FEEDING OF RUMINANTS ON FIBROUS CROP RESIDUES

ASPECTS OF TREATMENT, FEEDING, NUTRIENT EVALUATION, RESEARCH AND EXTENSION

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FROM THE EDITORS

These proceedings represent the work of over 60 Indian scientists and foreign consultants. They give a comprehensive picture of factors involved in the feeding of straw, including aspects of farming systems research, agronomy, economics, extension and gender issues. The papers were reviewed and edited by outsiders and many literature references are given in the papers as well as in separate bibliographies, in order to provide up to date information. To reduce the volume of the proceedings, the printing and papers were condensed as much as possible. Standard abbreviations are used for common terminology, such as DMI for dry matter intake and NDF for Neutral Detergent Fiber in order to condense the papers. Every session is preceded by a "summary paper" which sums up the state of the art on that particular issue. This summary paper was not presented during the workshop but prepared on the basis of the presentations and discussions during that session.

Thanks are due to all who have contributed to this final shape: the BIOCON workers, the consultants, the typists and many others. These proceedings are meant to serve a wide audience and comments are very much welcomed.

FOREWORD

I understand that the project on bioconversion of crop residues was taken up some time ago as a bilateral program by the Indian and the Dutch Governments, named BIOCON. The topic of research was 'improvement of the crop residues particularly in India'. The subject is of much importance in all tropical and subtropical regions mainly because there is shortage of feeds and also that the use of animals (particularly the large animals) is increasing. In view of these circumstances where animals are competing for grains with the human population, together with a shortage of green fodder, the need for better utilization of crop residues with supplemental feeding strategies cannot be overemphasized.

The work on crop residue utilization involves a cooperative effort by animal nutritionists, biotechnologists, economists, plant breeders, agronomists, farming systems and extension workers, and even gender specialists. This BIOCON project appears to be unique in that it has brought together workers from all these disciplines which have joined hands and who are taking an increasingly holistic approach to tackle the problem of feed shortage in particular and animal production in general. The importance of such work is further increased when the farmers have to go for strategic feedings in the scarcity situations like droughts, floods and other natural calamities. In many so-called developed countries, the issues of sustainability refer to problems related to excessive use of inputs and high individual outputs per animal. In our Indian conditions, sustainability implies the survival of livestock under conditions of scarce resources. The use of crop residues for animal feed is to be seen in this context.

I am sure that the contributions as presented in these proceedings will provide new insights to specialists and farmers for the development of new strategies in order to cope with the shortages that are likely to become more acute in the future.

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INTRODUCTION

FEEDING OF RUMINANTS ON FIBROUS CROP RESIDUES

INTRODUCTORY COMMENTS

Kiran Singh[1] and J.B. Schiere[2]

Increasing human populations require increased food production (WCED, 1987; Alexandratos, 1988). Crop land is used more intensively, stubble grazing and room for pasture land diminishes while waste land is eroding, i.e. possibilities of free grazing diminish (Jodha 1986). Crop residues will play an increasingly important role in the feeding of livestock (Singh and Rangnekar, 1986; Devendra, 1993). Increased and sustained crop production requires new approaches (Conway and Barbier, 1990) and whereas in the past livestock supported crop production by draught and dung production, the roles are slowly reversing and livestock depends increasingly on cropping. In short: systems of farming are changing fast. Feeding of livestock cannot be seen in isolation from the entire farm enterprise. Planting of fodder or feeding of straws affects the economics of crop production. A better understanding of the farm as a system is required, including issues of crop production and soil fertility. New or old methods of feeding that are useful in one farming system might not apply in other systems, hence the importance of "farming systems" work done in the project.

Farming systems work is the topic of the first session. The term "farming systems" covers many approaches and often leads to misunderstanding and confusion. The farming system work in the BIOCON project includes mainly farm level aspects of:
- identification of target groups/ recommendation domains/ agro economic zones that might benefit from available/ transferable technologies;
- traditional criteria to judge effectiveness of transferable technologies such as individual productivity of the cow, fodder yield, are complemented with more recent criteria (the effect of an intervention on total farm income, social position of the farmer and gender issues);
- design of new farming systems as required for extension and development;
- on-farm testing of lab results;
- participatory research and survey techniques (RRA, sondeo).

Farming systems work provides the basis of all further work on crop residues.

Predicting the effect of, or understanding the need for new technologies in animal nutrition requires a systematic approach but also knowledge of its fundamental principles. Systems work forces the nutritionists in the lab to produce up to date information on parameters such as feed intake, digestibility, substitution rates, associative effects and nutrient

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requirements. The use of nutrient requirements do not necessarily imply their application for maximum production per animal (Jackson 1981). It is increasingly agreed that the requirements for the whole range of animal production needs to be quantified. The second session gives a summary of historic and current developments in terms of nutrient requirements and evaluation.

The low nutritive quality of crop residues can be overcome in a number of ways, such as by treatments, supplementation or their combination.

Biological treatment with fungi is discussed in the third session. One new approach conceived in the project is the so called "Karnal process". However, biological treatment is not ready for field application and its understanding requires cooperation with microbiologists, plant physiologists and biochemists to solve or study inherent problems of this treatment, such as organic matter losses, disappointing increases of digestibility, difficult process control and potential toxicity problems.

Chemical and physical treatment is by and large beyond the on-station experimental stage except for work on some straws such as of sorghum, maize and fingermillet. The emphasis in the laboratories should be on determination of parameters of nutritive value, intake and substitution rates, in order to predict the economics of feeding treated or untreated straw in different farming systems. As discussed in the fourth session, much information is now available on economics and field application of these treatments, especially the urea/ ammonia treatment of rice and wheat straw.

Variability of straw quality and quantity caused by varietal or management aspects is discussed in the fifth session. Issues arising include the repeatability and magnitude of the variation, the choice between grain or straw production, or particularly between quantity or quality of straw. The BIOCON project was fortunate in this respect to have the collaboration of the AICRP's agronomists/breeders on sorghum and fingermillet. The exchange between crop and animal scientists has proven useful.

The subject of extension, with an increasing recognition of the importance of gender issues is covered in the final session. Quite often the scientist tends to come up with solutions (transferable technologies) for which the farmer (husband, wife or children) have no use, i.e. much time is wasted on ill conceived extension programs. Relatively easy progress such as was made during the green revolution, is difficult in highly variable systems with limited solutions. A proper understanding of the needs and problems of the diverse farming community is a pre-requisite for extension. In that sense it is important to note that modern concepts stress the two way traffic of extension, not only from the lab to the land, but also from the land to the lab. Researchers require input and feedback from the field, since many research topics are irrelevant for the field situation. They may be biologically sound but their economic or practical application is often very limited.

CONCLUSIONS

The improved use of crop residues for animal feed involves cooperation from many disciplines in research and extension. Quite some work is already done and needs to be applied where possible. Extension services at state level or from NGO's require the information of the research institutions of which in India the ICAR is the apex.

The task for the ICAR is to increase the interaction between field and research to face and predict both short term and long term issues. The next phase of BIOCON is aimed at strengthening this approach and the purpose of this workshop is to inform and to open doors to others, besides being a get together of the project workers themselves. The large area of work covered under the project thus far could not have been possible without the many scientists and other staff in participating centers of the project.

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LIVESTOCK PRODUCTION SYSTEMS, ANIMAL FEEDING AND FEED RESOURCES IN INDIA

--- KEYNOTE ADDRESS ---

R.M. Acharya [1]

I am very happy to participate in the International Workshop on Feeding of Ruminants on Fibrous Crop Residues being organized under the aegis of the Indo-Dutch Cooperative project on Bioconversion of Lignocellulotic Crop Residues for livestock feeding. We have now completed two phases of the project and after more than six years of work we are trying to review the total research effort on chemical and microbial treatment of lignocellulosic residues and their utilization as livestock feed. The scientists in the Department of Tropical Animal Production, Wageningen Agricultural University have made significant contribution in the planning and provided support in the execution of the project and some significant results have been obtained.

In India we have a very large livestock population comprising of 192.4 million cattle, 69.8 million buffaloes, 48.4 million sheep, 95.2 million goats, besides non-ruminants and other species of livestock. We have made significant progress in dairy and poultry production. The major limitation in increasing livestock production in addition to lack of organized breeding activity and health cover is the serious lack of adequate quantity and quality of feed. There has been a gradual reduction in grazing resources due to diversification of the range/grazing land for crop cultivation and marginalization of land holding. This trend does not allow us to divert any significant portion of land for fodder cultivation or even to provide sufficient quantity of crop residues for the livestock maintained by the small holders. Even in irrigated cultivated areas, with perennial sources of irrigation it has been realized that there is a need for diversification of agriculture. Dairy farming integrated with crop production can be an alternative, in which dairy serves as a source of cash income.

The main reason for a large livestock population, especially in ecologically poorer areas, are the risk factors such as drought and disease problems which cause serious decimation of the livestock population from time to time. Creation of feed security systems through the establishment of fodder banks utilizing chemically treated and densely baled locally available grasses, or crop residues such as wheat and paddy straw, sugarcane bagasse etc. may help, to reduce this risk. But most of the low producing animals are owned by poor people who have no other alternative source of livelihood and thus cannot reduce livestock numbers. Steps must therefore be taken to improve production through better utilization of available feed resources, reducing losses caused by mortality and morbidity due to infectious diseases and

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parasitic problems and through appropriate management and genetic improvement. We must simultaneously consider the development of more intensive livestock production systems which can be competitive with other crop farming practices.

Feed resources are a major limiting factor in exploiting the genetic potential in livestock. We cannot seriously think of meeting of nutritional requirement of improved livestock from the kind of feed resources that are conventionally available. These are primarily crop residues and other poor quality roughage and foraging materials. The large portion of crop residues are rice and wheat straws, stovers of sorghum, millets and maize and sugarcane bagasse from sugarcane processing. Most of these materials are low in protein and are highly fibrous, i.e. low in energy. Methods for breaking down lignocellulosic bonds in these feeds through chemical and microbial treatments have been developed with variable success and such treatments have led to improvement in their intake and utilization. The most successful of these methods is ammoniation of straws, using urea. The second one is steam treatment of sugarcane bagasse with or without addition of urea and molasses.

In India, we have been working since late 1960s on improving the nutritive value of feed resources and agro-industrial by-products. Actually already in 1940 a project was sanctioned on the use of NAOH to improve straw quality. A number of non-conventional feed resources have been identified and are now being utilized in the compound feed industry. The All India Coordinated Research Project on Agro-industrial Byproducts is doing work in this area. Identification of these feeds and their availability and assessment of their nutritive value has been related to long-term performance trials. There are inadequate studies on the incriminating agents limiting the utilization of nutrients and methods for removing them. Under this Indo-Netherlands bilateral cooperative project, work has been done on microbial degradation of lignocellulosic materials using the *Coprinus* fungus. The treatment suggests a sizeable loss of dry matter, but is associated with an increase in the microbial protein content of feeds. The time needed for the treatment has now been reduced which also reduces dry matter loss. Similarly, under an Indo-USAID cooperative project work has been initiated on microbial degradation of organic animal farm wastes, slaughter and marine by-products and their utilizaton as animal feeds.

A major problem with the crop residues is their low bulk density. Treatments are necessary to improve their utilization and reduce the bulk so that the cost of transportation and storage can be minimized, in cases where transport over large distance is required, such as during droughts or other emergencies in a large country such as India.

More accurate information is needed on the availability of feed resources since these are based on indirect estimates utilizing information on areas under different crops and the ratio of grain to residues. A sizeable quantity of straws, stovers and other by-products are still not utilized for animals. More accurate estimates of available feed resources and their utilization by the farmers is necessary. It will also be necessary to identify regions with surpluses and chronic shortages, so that systems of animal feed security through establishment of feed and fodder banks can be developed.

It is unfortunate that much of the knowledge on feed utilization has not reached farmers for extensive adoption. It is necessary to ensure that treatments which are to be transferred to the farmers are tested on their farms. For certain farming systems it may be useful to develop commercial units which can make treated feeds available to small farmers. Such feeds could also be used in developing animal feed security systems. Long term feeding trials should also study the negative effects of the presence of incriminating or toxic agents. In this connection the ICAR has established a Central Laboratory as a part of Coordinating Unit of All India Coordinated Research Project on Agro-industrial Byproducts to look into the toxicological and incriminating agents present in non-conventional feed resources.

It is necessary that on-farm client oriented research on a farming systems basis and with farmers participation is done in livestock production. This will allow us to learn about existing livestock production systems, their limitations, the interventions that can be made on a-priori knowledge and to identify the problems on which on-farm or on-station research needs to be taken up. FSR/E (as suggested for the next phase of the BIOCON project) would be an appropriate research approach compared to the one which is being followed currently.

I hope that the cooperation with the Netherlands in the area of livestock production will be further strengthened and the present research program on improving nutritional value of crop residues will be extended to take up on-farm trials involving methods of densification of straws, establishment of feed security system and on-farm research on livestock production systems.

FIBROUS CROP RESIDUES: STRATEGIES FOR THE EFFICIENT USE AND DEVELOPMENT OF FEEDING SYSTEMS

C. Devendra[1]

SUMMARY

Strategies for the efficient use and development of feeding systems based on fibrous crop residues in Asia are discussed considering the advances of knowledge in feeding and nutrition, the relevance of applying the available information and the intensified use of feed resources as a means to increase the current level of productivity. The populations of ruminants (buffaloes, cattle, goats and sheep) are sizeable but need to be more completely utilised. The justification for more complete utilisation of fibrous crop residues is associated with:

- *a marked imbalance between animal densities, feed availability and low productivity of meat, milk and draught;*
- *prevailing ruminant production systems, that are resistant to change, although predictable shifts within the system are likely due to intensification, for example shortage of grazing land;*
- *potential possibilities of extending technologies on feedstuffs to the real farm situation.*

Over the period 1977-1990, 27 meetings were held on the use of fibrous crop residues in Asia, without discernable impact on expanded utilisation of the available feeds. There is a need to formulate and demonstrate rural-oriented strategies that can give priority to the on-farm use of available feeds. Extending the information on fibrous crop residues to on-farm situations, is considered in two phases:

- *the information needed by farmers and their advisors,*
- *mechanisms for delivering information to farmers.*

The benefits of addressing these phases more thoroughly will increase the current level of animal production and socio-economic status of the rural poor.

INTRODUCTION

Strategies for more intensive, efficient use of, and the development of feeding systems based on fibrous crop residues depend on:

- the existence of considerable quantities of feeds which are potentially useful to animals;
- efficient utilisation that can demonstrate beneficial economic advantages and generate packages of technologies;
- potential for intensive and large scale development which is relevant for the needs of farmers.

These prerequisites together should promote development that is consistent with self-reliance and rural development. Implicit in this objective is the impact of this strategy on productivity

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from animals. With specific reference to the Asian region, this is particularly appropriate since animal production has failed to keep pace with the growth and demand of the human population. The contribution by animals to national targets is far from being realised relative to the contribution by crops. This has raised doubts about the total production of existing animal production systems, the utilization of the natural resources, and current efforts to maximize the contribution from animals to development.

Central to the problem is that the components of the animal industries, and notably ruminants, are inadequately exploited and managed in the developing countries. This is reflected in low per animal performance (meat, milk or fibre), and more particularly, the potential to significantly improve this level of performance through improved and more efficient nutritional management. The two main constraints that cause the low level of production per animal concern the use of the available feed resources, and the application of advances on the principles of feeding and nutrition and information on feedstuffs. Incomplete use of the available feed resources, combined with poor feeding systems contribute to low production from animals, suggesting inefficiencies in project planning and implementation. These observations are exemplified by the situation in Asia where major advances in feeding and nutrition have been made, but the impact of these on the level of production in ruminants in general is low.

Crop residues, agro-industrial by-products, and non-conventional feeds provide a link between crops and animals. In many developing countries, mixed cropping is the main pattern in agriculture, so that ensuring efficiency in feed utilization is important for the stability of farming systems. The poor nutritive value of crop residues limits intake, but efforts to increase utilisation of the available feeds present possibilities to increase the current level of output from the animal resources (Devendra, 1989).

In this paper, the reference to fibrous crop residues (FICR) includes agro-industrial by-products (AIBP), and also non-conventional feed resources (NCFR).

ANIMAL RESOURCES

It is appropriate to keep in perspective the types and magnitude of the animal resources in Asia, their percentage of the total world population and the average annual growth of each species (see Table 1).
Ruminants are generally owned by small farmers, peasants and landless labourers. They are mostly distributed in mixed small farms in which they make an important contribution to sustainable agricultural systems. In contrast, pigs and poultry constitute advanced animal industries in many countries in Asia. The main reasons for this are the availability and successful transfer of

proven technology in pig and poultry production, the ease of importing feedstuffs for them, a large and ready market for the products and the rapid turnover of capital investment. The pig and poultry sectors have already assumed industrial proportions and are usually found in urban-fringe areas which can absorb the growing domestic market outlets for the products. In view of the priority on the development of ruminants in most countries in Asia, expanding the use of AIBP and NCFR should take these species into account. It is important however, that the attributes of ruminants be recognised in the quest to maximize their productivity.

Table 1 Animal resources in Asia based on current trends (FAO, 1988a)

Species	Population (10^6 heads)	As % of total world population (%)	Annual growth rate(%) 1975-1985	projected 1989-2000
Ruminants				
Buffaloes	132.5	98.0	1.6	1.8
Cattle	384.0	30.4	0.8	1.4
Goats	295.8	56.8	1.6	1.9
Sheep	331.6	28.3	0.7	1.1
Donkeys	20.9	50.5	2.1	2.0
Camels	4.5	23.9	0.7	0.8
Horses	17.1	26.2	-ve	-ve
Mules	5.9	38.2	2.8	2.8
Non-ruminants				
Chickens	4019.0	39.3	9.5	8.3
Ducks	453.0	87.3	2.7	2.9
Pigs	405.0	49.2	1.2	1.4

Table 2 Per caput supply of animal products in Asia (FAO, 1977; 1988; kg/year)

Commodity	1977	1988
Beef and veal	0.29	0.33
Buffalo meat	0.42	0.62
Goat meat	0.18	0.22
Mutton and lamb	0.07	0.29
Buffalo milk	7.80	8.50
Goat milk	0.44	0.58
Cow milk	7.70	9.82
Eggs (#)	337.30	679.60

Table 3 Availability of fibrous crop residue in Asia

Category	Quantity (10^6 MT DM)
Traditional feeds*	2039.4
Non-conventional feeds**	58.4
Total	2097.4

Notes: * Projected from Kossila (1984)
** Projected from Devendra (1988)

Table 4 Priorities for the utilization of fibrous crop residues by animals in Asia

Feed source	Characteristics	Species
Good quality crop residues (e.g. casava leaves)	high protein high energy	Pigs, ducks, lactating ruminants* and use as supplements by meat animals
Medium quality crop and (e.g. sweet potato vines)	Medium protein	Pigs, ruminants* (meat reproduction milk), camels and donkeys
Low quality crop residues (e.g. cereal straws and	low protein very fibrous	Ruminants* (meat and draught), camels and donkeys

Note: * ruminants refer to buffaloes, cattle, goats and sheep

Table 2 summarizes the trends in per caput supply of animal products in Asia between 1977 and 1988. Although increased production is apparent for all commodities, in general, and with respect to goat meat, beef and veal and buffalo meat, the increases were small. Mutton and lamb supply increased considerably in 1988, probably due to increased imports. Significant changes in the supply of both buffalo and cow milk were made. The supply of chicken eggs more than doubled over the same period.

AVAILABILITY OF FIBROUS CROP RESIDUES

It is relevant to keep in view the amount of FICR that is generated in Asia (Table 3). The total availability of these from field and tree crops is about 2098 x 10^6 tonnes of dry matter, and increases at the rate of 2.9% per annum.

PRIORITIES FOR FEED RESOURCE USE

The use of AIBP and NCFR in Asia according to their potential value and importance especially to individual species of animals are summarized in Table 4. The bulk of the FICR is dry and of poor quality and are therefore only useful for low or medium levels of production and draught animals.

DEVELOPING FEEDING SYSTEMS BASED ON FICR

Three main issues need to be considered for developing feeding systems appropriate to small farms in Asia: the distribution of ruminants, prevailing ruminant production systems and application of research results.

Table 5 Extent and distribution of permanent pastures, forests, woodlands and ruminant livestock (FAO, 1986)

Region	Permanent pastures (10^6 ha)*	Forest and woodland (10^6 ha)*	Ruminant livestock units (10^6)**
Developing market economies			
Africa	631.2	645.7	138.4
Asia & the Far East	109.8	220.5	356.3
Latin America	512.7	928.8	253.2
Near East	267.6	95.2	67.0
Total	1521.3	1890.2	814.9
Asian centrally planned economies	409.8	188.6	100.5
Total developing countries	1931.1	2078.8	915.4
World total	3170.8	4086.6	1319.6
As % of world total	60.9	50.9	69.4

Notes: * Refer to 1985 data
** Conversion factors: buffalo 1.0, cattle 0.8, goats and sheep 0.1

Distribution of ruminants

Table 5 provides data on the distribution and access to permanent pastures, forests and woodland. Particularly significant is the high concentration of animals in Asia, and the marked imbalance between the total ruminant livestock units and available permanent pastures here compared to the other regions. This situation and the growing animal populations further emphasize the need to ensure that all available feeds are put to maximum use in development strategies that can sustain animal production. The very high animal densities in Asia and inadequate land for grazing, are exacerbated by chronic annual feed shortages throughout South Asia, notably Pakistan, India and Bangladesh, despite attempts to use as much of the available feeds as is possible. Table 6 indicates the trends in the feed balances in India between 1970 and 1984. Two major conclusions are apparent:

- feed deficits and the malady of undernutrition was a continuing problem;
- there has been a distinct trend towards reducing feed deficits despite increased animal populations over the 14 years.

These trends probably reflect improved feeding systems, more efficient use of the available feeds, and increasingly intensive systems of production. Whether these approaches are adequate and can be further improved in terms of scale and magnitude is a matter of debate. Reddy (1990) has recently pointed out that many NCFR remain to be more widely used in India, implying that there is still scope for reducing the feed deficits.

Table 6 Trends in feed balances in India (adapted from Reddy, 1990)

Nutrient	1970			1984		
	availability[a]	requirement[b]	% deficit	availability[a]	requirement[b]	%deficit
Energy (10^7 Mcal ME)	6162.8	9877.9	37.6	7399.4	10933.5	32.5
DCP (10^4 mt)	113.2	297.8	61.9	135.1	344.0	54.0

Notes: [a] ME - Metabolisable Energy
DCP - Digestable Crude Protein
[b] Of herbivores (buffaloes, cattle, goats, sheep, asses, yaks and chauri) and non-ruminants poultry and pigs)

Ruminant Production Systems

Ruminant production systems in Asia can be categorised as follows:

i) Extensive systems;
ii) Systems combining arable cropping with livestock,
- Roadside, communal and arable grazing systems;
- Tethering;
- Cut-and-carry feeding;

iii) Systems integrated with tree cropping;

These ruminant production systems are unlikely to change in Asia and the Pacific in the foreseeable future, unless massive capital resources are used, or feed resources change drastically. New proposed systems and returns from them would have to be demonstrably superior and changes from them would need to be supported by major shifts in the use of resources. (Mahadevan and Devendra, 1986; Devendra, 1989). However, it is quite predictable that there will be increasing intensification and with it, a shift within the prevailing systems, especially from extensive systems to systems combining arable cropping with livestock. This situation is especially likely in countries in South Asia where land is increasingly limited due to increasing human and animal populations. Changes must be introduced gradually, consistent with income stability and low risk must be ensured. The principal aim is to make maximum use of the basic feed resources available. This means using available crop residues and low quality roughages to maximum advantage. In addition, systems should be developed to supply essential supplementary feeds (legume forage, agro-industrial by-products and other feed concentrates not directly used by pigs and poultry).

Application of research results and information on feedstuffs

Considerable accumulated information is available on the utilisation of feedstuffs in Asia. Most of this remains unused at experimental and University Research Station levels. Numerous meetings have been held and those that have addressed FICR are summarized in Table 7, still excluding annual meetings on the subject by the Indian Council of Agricultural Research (ICAR) supported All India Coordinated Research Project on the Utilisation of Agricultural By-products and Industrial Waste Materials for Evolving Economic Rations for Livestock and national meetings in other countries. In Asia, over the period 1977 to 1990, there have been a total of 27 regional meetings, equivalent to about two meetings annually. The results and information presented in all these meetings are generally sound and have significantly contributed to fundamental knowledge. Yet, these have not made any discernable impact on more intensive and expanded utilisation of the available feeds. Doyle et al. (1986) concludes that the importance of evaluating new technologies through on-farm testing and demonstrations far out-weighed the need for further documentation of the effects of supplementation or pre-treatments.

Table 7 Meetings on fibrous crop residues and feeding systems in Asia (1977-1990)

Country	Year
Bangladesh	1981, 1982, 1983
India	1986, 1988a, 1988b, 1990
Indonesia	1981, 1985
Japan	1983, 1987
Malaysia	1977, 1986, 1987
Pakistan	1983
Philippines	1980, 1981, 1989
Sri Lanka	1983, 1986
Thailand	1984a, 1984b, 1987

Note: the respective proceedings are mentioned under the country and year in the list of references

One other observation about these meetings and their frequency is the focus of the research. Many of the topics in the past, have tended to concentrate mainly and unfortunately on chemical and more recently, on microbial treatments. The original rationale for the research in terms of relevance and usefulness for optimum use of the resources or alternative approaches and usefulness as potential interventions do not appear to have been discussed initially. One unfortunate and associated development, is the parallel tendency by laboratories between-countries to undertake duplicating research programs, with consequent inefficient resource use. Given the result that the chemical or microbiological options for the utilization of FICR, such as rice straw has not led to any impact at the farm level, further suggests the need for more detailed discussions and planning of such research programs, which can concurrently consider various approaches and a balance between fundamental and applied on-farm activities. Central to this search is the efficient use of FICR as the basal feed to supply nutrients for maintenance and part of the production needs, and beyond this, to enlist strategic supplementation to make good the nutrient requirements for production (meat, milk and draught).

The work is particularly relevant for ruminants (buffaloes, cattle, goats and sheep). The pig and poultry industries have made major increases in production through the application of advanced technology, improved breeds, and feeding mainly on imported energy and protein concentrates.

What causes the poor dissemination of on-farm applicable information on feeds, feeding and nutrition, and feeding systems? There are several reasons for this, such as:
- failure to distinguish between "perceived" and "real" needs of farmers;
- poor research focus and planning;
- inadequate and/or appropriate research protocols;
- no or very limited inter-disciplinary research and development;
- weak institutional linkages;
- poor research-extension links in the program from inception to delivery systems;
- no development orientation;
- inadequate monitoring of field work, feed back on failures, rate of adoption and lessons learnt.

ON-FARM APPLICATION OF FEEDSTUFF INFORMATION

The application of feedstuff information and the accumulated knowledge on feeding and nutrition merits the highest priority to increase production of meat, milk and draught. On-farm animal research (OFAR) is probably the only accurate assessment of whether new technology packages are acceptable both economically and socially to the farmers as they take into account all the interacting components unique to farming systems. OFAR is a means of identifying and addressing the constraints to adoption of new feeding systems, and the extent to which they contribute to sustainability (Devendra, 1990). Two phases are involved :

Phase I: Information needed by farmers and their advisors
- choice of feeds and their availability over seasons.
- nutritive value: detailed information on constituents, prediction of changes during periods of production, capacity to meet production target and capability of filling any nutritional gap.
- strategic supplementation: On animal performance and on sustained production of the basal feed resource.
- feeding system.
- level and type of production (meat, milk and/or draught).
- realistic production targets.

Phase II: Mechanisms for delivering information to farmers
- methodology: balance between fundamental and applied research.
- linkages across disciplines and institutions.
- demonstration of economic benefit.
- large scale on-farm testing.

- in situ utilisation.
- farmers participation.
- definition of models for feed resource development.

The above listing is not exhaustive, but needs to be considered in planning towards demonstration of effective utilization. Many research projects on feed utilization stand to be criticised because several of the elements listed are missing and funding is mainly focused at fundamental research. Much of the work undertaken is only perceived to have application and relevance without proof of demonstration of improved productivity in animals at the farm level.

The planning of effective development strategies for the efficient use of FICR demands much more effort and organisation, definition of clear responsibilities at all levels of implementation, collective participation and commitment of the various people in the project. Some of these issues will be discussed in more detail in other presentations in this meeting.

CRITERIA FOR ON-FARM ACTIVITIES

Several criteria need to be considered for on-farm work, such as objectives of production, the treatments involved, the methodologies to support the work, the measurements to be undertaken, type and value of the inputs used and the outputs derived from the experiment, extent of farmer participation, issues related to the economic analysis of the results, and marketing.

To ensure attention for all these aspects as well as smooth conduct of the work, consideration also needs to be given to how intensively the on-farm work will be monitored. The stability and success of on-farm testing depends to a large extent on minimization of risk factors, possible compensation, renumeration in the form of produce from the results, and the enthusiasm of farmers. A useful recent publication on appropriate methods for conducting on-farm animal research, procedures and economic analysis is Amir and Knipscheer (1989).

By the turn of this century little suitable land will be left to increase the area of arable crops (FAO, 1988b). The quantity of crop residues will therefore remain static, and if the production of meat, milk and draught power are to be increased, more intensive systems of production and increasingly higher per animal output is essential. The FAO (1988b) further emphasizes that advances in animal productivity can only be achieved with the availability of technologies, diffusion of knowledge and application, in which on-farm experimentation was crucial. These issues further emphasize the need to focus thoroughly on the choice of feeds and the relevance of technology development and application at the farm level. With FICR, large scale intensive utilisation on-farm merits the highest priority to increase the current contribution of animals to human welfare.

An important aspect of planning towards wider use of FICR is the measurement of possible impact on animal production or farmers income. Research and development programs need to address the beneficial value of the derived technology with reference to such criteria as value added; real benefits to small farmers, peasants and landless labourers; income generation; pollution control and possible expansion in animal production activities. The latter refers to more intensive use of the totality of the animal resources to include not only ruminants (buffaloes, cattle, goats and sheep) and non-ruminants (pigs, chickens and ducks), but also other herbivores like the camels and the donkeys.

MORE EFFICIENT USE OF THE ANIMAL GENETIC RESOURCES

Strategies for more efficient use of feedstuffs based on FICR must necessarily also consider better use of the animal genetic resources. The elements in these considerations include species, breeds within species, and control of numbers that are consistent with the objectives of production. Unimproved indigenous animals with moderate levels of animal performance may be biologically inefficient, but have a longer life span and may therefore be more economic than "improved" animals.

Table 8 Current and projected metabolisable energy requirements (ME) for maintenance of goats and sheep

Species	ME Requirements (10^9 MJ)			Requirement/yr
	1970	1988	2000	(1970-2000)
Goats	0.42	0.68	0.99	4.4
Sheep	0.25	0.34	0.42	2.3
Total	0.67	1.02	1.39	3.6
ME requirements of goats and sheep as % of total requirements by ruminants (%)*	0.02	0.02	-	

Note: * The daily requirements for maintenance of ruminants per head used in the calculations are as follows; buffaloes 56.1 MJ, cattle 42.7 MJ and goats and sheep 6.5 MJ/day

The importance of planning a strategy that also integrates type of animal and the requirements is exemplified by the complex situation in India where there is intensive pressure on the use of land and there are chronic annual feed deficits. The calculations focus essentially on the energy requirements for maintenance for 1977 and 1988 and projections for the year 2000 (Table 8). The maintenance requirement used is 424.3 $kJ/W^{0.75}$ kg for goats (NRC, 1981). When these calculations are also related to the requirements of the other ruminants (buffaloes, cattle and sheep), and the available feed resources, the annual metabolisable energy (ME) requirements exceed availability by between 26 and 34 per cent. The feed deficits are underestimated as they do not include the energy requirements of non-ruminants and other herbivores such as camels, donkeys, mules and asses.

ALL-YEAR ROUND FEEDING SYSTEMS

Expanded and more intensive utilisation of the FICR in appropriate feeding systems needs to consider finally, the development of all-year round feeding systems appropriate for ruminants. Such systems are important since they take into consideration how and when FICR ought to be utilised, the purpose, efficiency of utilisation into useful produce, seasonal changes such as drought, and extent and relevance of conservation. More particularly, the strategy also ensures that there are sufficient and a continuous supply to meet the production requirements of animals.

All-year round feeding strategies can define the critical constraints at particular seasons for either dietary energy and protein. This enables introduction of interventions such as strategic supplementation of proteins.

Since Asian agriculture is characterized essentially by mixed systems of crops and animals in which small and large ruminants are abundant, the approach to the development of all-year round feeding systems for these ruminants and also non-ruminants will also contribute to the stability of farming systems. At the present time year-round feeding systems have been inadequately addressed in most countries and merit more attention as part of the efforts to intensify the use of FICR.

CONCLUSIONS

Intensification of approaches to develop feeding systems based on FICR in terms of large scale effort on on-farm, merits urgent attention. Well developed programs can result in increases in the current level of productivity from animals. The increases can only be realised however, from more complete matching of the available genetic resources with feed availability and in awareness of biological attributes. The issue which merits the highest priority, is application of the available information based on the advances that have been made on the principles of feeding and nutrition. These need necessarily to be targeted to individual animal species in real farm situations throughout Asia.

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SESSION ONE

FARMING SYSTEMS RESEARCH AND EXTENSION

FARMING SYSTEMS RESEARCH AND EXTENSION

Reasons why farmers reject technology include a lack of a farming systems perspective by policy makers, scientists and extension staff. A farming systems perspective is needed to make research more relevant to actual farmers needs and to more effectively target technologies to specific recommendation domains which can be defined by using Farming Systems Research and Extension (FSR/E) principles. Most research ends too early and most extension projects start too late. FSR/E helps fill this gap in a number of ways and the Indian Council of Agricultural Research is paying more attention to entire farming systems as a basis for introduction of technologies through demonstrations.

The Farming Systems Research has many definitions and objectives, ranging from pure academic research (FSR sensu strictu) via programs that aim at development (FSR/extension or FSR/development), to the design of new systems (New Farm Systems Development) as discussed in the paper of Patel et al.. *Among others, FSR/E essentially tries to:*

- *see technical innovations in their context, i.e. livestock improvement cannot be considered separately from the effects it may have on other parts of the system. For example, an increased labour requirement for livestock may conflict with labour requirement of existing cropping patterns and household activities;*
- *to establish the needs of the farmer according to his or her specific production conditions or farming system.*

This section of the workshop dealt with economic models that can be used in the analysis of mixed farming systems. Some of the session papers carried out fairly detailed analysis of optimization of farm resources using new technologies. The papers, in most cases, represent work that has been completed or is ongoing, and they represented examples of the various phases of FSR/E that are needed.

First, the paper by Patel et al. *provides the overview of how principles and techniques of FSR/E could be applied to animal research/extension programs in India in general and to the BIOCON project in particular. An important first step is the description and classification of Farming Systems according to specific research objectives and purposes.*

The paper by Jain and Dhaka represents a major component of the descriptive phase of the FSR approach. The paper briefly reviews some of the principles involved in farming system classification, it reviews selected Indian and overseas studies and it provides data related to livestock sub-systems in India. A specific framework is then suggested for use in the FSR/E work being planned to support livestock development objectives.

As an introduction to the papers dealing with applied economic analysis of mixed farming systems, the paper by Sitaramaswamy and Jain provides an overview of available models, their strengths *and weaknesses, applicability to specific research problems and then makes recommendations on how they should be applied in proposed FSR/E work.*

The next two papers C.B. Singh et al. *and Vijayalakshmi* et al. *provide examples of how increasingly complex methods of economic analysis could be used in India for analysis of resource use efficiency in mixed farming systems. These provide a good basis for further work on the analysis of component technologies and the introduction of technologies into the whole farm system.*

The final two papers are concerned with aspects of survey techniques and measurement problems that will need to be considered by the FSR teams. The paper by Patil et al. *stresses the large variations in resource availability, cropping patterns, type and breed of animals and feeding patterns that can be expected during the descriptive phase of FSR. A particularly acute problem in the modelling stage is how to make accurate estimates of nutrient intake by grazing animals under field conditions and the bias that this can introduce into feed demand-supply relationships. The paper by Rangnekar* et al. *outlines the need for NGO's to do FSR/E and also the practical problems involved in conducting large surveys and then quickly and effectively using this data for FSR description, analysis and extension work.*

(With thanks to A.J. De Boer.)

RECOMMENDATIONS ON FARMING SYSTEMS RESEARCH/EXTENSION

Farmings Systems Research (FSR) is a rational approach to guide research and development in developed as well as developing countries like India. FSR aims to improve the productivity and income levels in the whole farming system through the development of appropriate technologies and interventions by multidisciplinary teams of scientists on one hand and an efficient use of scarce resources on the other. Simultaneously FSR also intends to identify constraints for development as well as to provide feedback to scientists for finding solutions to the problems faced by the farmers. Therefore, FSR needs to be initiated in different zones of the country.

Modeling of Farming Systems has its own significance in different contexts according to the decisions to be supported and the purpose to be achieved. Simulation models using total systems approach are well suited in Farming Systems Research.

Economic evaluation of existing and emerging Farming Systems and technologies is a pre-requisite for the development and introduction of improved farming systems. Therefore, selection of various dairy and crop enterprises along with relevant technologies in the mixed farming system should be mainly based on the criteria of income and employment generation. In relatively high potential areas with adequate infrastructure for crop and dairy development, the cross-bred cattle sub-system may be encouraged for increasing income and labor productivity of small holders.

In order to make effective use of linear programming techniques for optimising farm resources, linkages between and within sub-systems need to be identified and quantified. Similarly, multiple use of critical resources in different months and operations should also be assessed and incorporated in the model. Therefore, comprehensive data bases from both primary and secondary sources should be created. Model construction for a particular farming system should take into account a time dimension for arriving at optimum plans, more so for crop - dairy integration where frequent changes in herd size are often required.

FSR-approach can be of multiple utility. Thus it should form an integral part of the workplan of development organisations. FSR implies a holistic and participatory approach with due weightage to farmers' participation. Many NGO's are already sensitized to most of these aspects. Improvement of survey and data analysis techniques would make studies more critical and accurate. Special attention is needed to involve the poorer section of society and women in the studies. Gathering factual data in a new area is difficult but NGO's can cope with this problem. Discussion of findings with field staff is very useful. Developing FSR approach suitable to our conditions is recommended. It should not be looked upon merely as a research study.

In view of the large variation in resource availability, cropping pattern, type and breed of animals, it is important to assess availability and requirements of feeds and fodders in different periods for dairy animals in different agro-climatic zones of the country for making appropriate feeding recommendations. This could help the farmers in optimum utilization of feed and fodder resources. There is a severe limitation with regard to accurate estimation of nutrient intake by grazing animals under field conditions for want of valid methodology. Therefore, attention should be paid by the scientists to develop suitable methods for more accurate estimates.

In order to classify the country into macro-regions to assist the Farming Systems approach, one should take crop and livestock production parameters as well as socio-economic variables in addition to topography, soil type, geographical formation, rainfall, irrigation, cropping pattern etc. The categorization of farms could be done by computing standard farm units for various enterprises based on net returns to land, labour and capital rather than farm size/herd size only.

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FARMING SYSTEMS RESEARCH: CONCEPTS AND APPLICATION FOR THE BIOCON PROJECT

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SUMMARY

Evolution of the Farming Systems Research and extension approach is set out in the context of (a) bridging the gap between research and extension, (b) facilitating information flows between farmers and researchers, (c) classifying and defining groups of farms into recommendation domains to help target technologies, (d) helping to design on-station research programs of greater relevance to farmers and (e) helping to set research priorities and allocate overall research resources within and between commodity improvement programs. The concepts are defined and followed by a stagewise approach to implementation. Reference is made to other papers in these proceedings that work out special issues. Special problems of implementing FSR/E with animals are highlighted and the need of FSR/E for realistic analysis of mixed farming systems is noted.

INTRODUCTION

Agricultural development reflects sustainable increases in factor productivity of farm resources. Thus, output per unit of land area, labor, and capital increases over time. Agricultural research is a major contributor to increased factor productivity and is thus referred to as the engine of agricultural growth.

Serious questions, however, have been raised about the quality of this "engine", particularly about its impact on the small farm sector (Conway and Barbier, 1990). Does it have enough power to initiate and sustain growth in an equitable fashion ? Is growth in farmer welfare commensurate with growth in total factor productivity ? And does it always use available meagre resources in an efficient manner ?

Economic analysis has confirmed high rates of return to agricultural research (Boyce and Evenson, 1976; Hayami and Ruttan, 1984) and major increases have occurred in the productivity of some cereal crops, notably rice and wheat. But there exist regional, sectoral, commodity and farm-type imbalances in the present research system which need to be corrected. Research efforts have been lopsided towards the crop sector, and investments in research on livestock, horticulture, fisheries and forestry have been abysmally low (Fitzhugh and De Boer, 1979).

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Although we know that farm women play a key role in Asian agriculture, their pattern of activity and decision-making processes have been neglected, resulting in wasted effort in targeting of extension programs. Some of these gender issues are discussed in session 6 of this workshop.

Finally, we find an overemphasis on disciplinary and commodity research as opposed to interdisciplinary research focussed on farmer problems in specific agro-ecological zones. The BIOCON project, fortunately, represents the latter type of effort which calls for a "Farming Systems Research and Extension" approach.

FARMING SYSTEMS RESEARCH

Farming Systems Research and Extension

FSR in general knows many definitions and concepts. They are reviewed by Simmonds (1986), who distinguishes three types:
1. the FSR *sensu strictu*: in-depth analysis of Farming Systems, as they exist, which is essentialy an academic activity;
2. OFR/FSP (on-farm research with a farming systems perspective), a practical adjunct to research which seeks to test the socio-economic suitability of research ideas on farm, before recommending extension. This is also called FSR/E or FSR/D;
3. NFSD (New Farm Systems Development) which seeks to develop complex radical changes, rather than the stepwise change characteristics of OFR/FSP.

Many more characterisations and definitions can be given but this paper focuses on FSR/E, which most resembles OFR/FSP in the Simmonds concept.
One of the main strategies to improve the quality, relevance, and small holder focus of agricultural research has been the introduction of the so called "farming systems" approach to research and extension. Farming Systems Research and Extension (FSR/E) is now a well established methodology. Although new in name, many aspects of FSR/E have been introduced in farm management, economics and agricultural research programs before the FSR/E concept became popular. The Operational Research Project (ORP) of the National Dairy Research Institute (NDRI) Karnal is an example of an applied research program that has used many aspects of the FSR/E approach since 1975; whereas FSR/E is generally dated in 1978 with the publication of the TAC Report (TAC, 1978) which formalized many approaches being tried by international centres of agricultural research.

What are FS's and recommendation domains?

A farming system (FS) is a more or less stable arrangement of farming activities managed by a household. It is called a system as it can be viewed as a collection of interdependent and interrelated elements that act together to accomplish a given task: the satisfaction of the needs of the farming household. In India, most small farms fall within this definition. However, there are some large, commercial farms where weak linkages exist between agricultural activities and households. Farming systems can be grouped together based upon similarities of elements, linkages, activities and household objectives, thus defining target groups or recommendation domains for research and extension activities.

What is FSR?

Farming Systems Research (FSR) is an approach to agricultural research and development which is aimed at improving the productivity of existing farming systems. It is characterized by:

- a holistic approach;
- a focus on interdependencies of individual farming systems components such as the interaction between crop enterprises and the animal enterprises (e.g., crop by-products are fed to animals while animals provide traction and sometimes manure for crops);
- main emphasis on small farms although it can be applied to larger farms, and
- a focus on the household (HH) as a decision-making unit realizing that this HH operates under a given physical, biological and socio-economic environment.

FSR is also called FSR/E or FSR/D in order to emphasize the need for linkages of FSR with Extension (E) and Development (D).

Why FSR/E?

Despite the successes of the Green Revolution, concern about the impact and equity of agricultural research increased steadily in the seventies (Griffin, 1974). Research managers and policy makers were worried because solutions and recommendations offered by scientists proved inapplicable to farmers' circumstances. Simultaneously, questions arose as to whether scientists were developing the appropriate technologies (solutions), but also if they were really working on the right problems! Scientists tended to work on relatively small and specialized components of the overall set of farming activities, finding solutions to partial problems without realizing where such problems fit in the whole farming system and what other farming activities would be affected by the application of these "new solutions". The BIOCON Project initially focussed on discrete, specialized research activities that, taken together, had the objective of improving overall ruminant animal nutrition in India. The need now is to use FSR/E approaches to identify the bottlenecks and to develop models to solve various problems of the small farmers keeping in

view the whole farming system. So the need was realized for improved :
- understanding of the farming system;
- understanding of the farmers' problems;
- evaluation of new technologies under farmers' conditions.

As rapid gains were made in agricultural research in many developing countries, weaknesses in the institutional linkages between research and extension also became evident, and FSR became FSR/E where methodologies were developed to deal with this linkage problem as well.

We must recognize that the Technology Innovation Process (TIP) represents a continuation of research and extension (McDermott, 1987) where, typically, research ends too early and extension starts too late, leading to a gap. FSR/E plays a critical role in bridging this gap. Models, such as those typically constructed by FSR workers, assist in:
- helping us understand and explain the processes with which research and extension must deal;
- helping to stimulate imagination and help gain insights into managing the research and extension process and
- helping to facilitate communication among those involved in the research and extension process.

FSR/E is relevant for the BIOCON Project for many reasons. The value of crop residues is typically maximized in systems where the crop and the animal components interact in an optimum manner. The project emphasizes the applicability of new crop residue utilization technologies. Besides, the project also tries to identify field level bottlenecks and give feedback to researchers to find solutions.
The Operational Research Project (ORP) of the National Dairy Research Institute was launched to improve productivity, employment and income levels especially on small farms through the transfer of new technology for both dairy and crop production. Simultaneously, it also aimed at identifying various constraints in the transfer and adoption of new technologies by the crop and dairy sub-systems, and providing feedback to the scientists. Thus, ORP follows not only Lab to Land, but also a Land to Lab approach in finding solutions for problems encountered by farmers.

Stages in FSR/E

It is instructive to conceptualize FSR/E as a multiphase process. The number of stages presented by different authors (Rohrback, 1981; Shaner *et al.*, 1982; Simmonds, 1985) are not always the same, and they generally vary from four to six. Here we will present a five-stage process, purposely distinguishing the pilot development program phase from the extension phase. Diagram 1 shows the five phases/stages. Each stage provides feedback to the scientists for research program design and priority setting.

Actually, in a full fledged FSR/E program, most stages of FSR/E will occur simultaneously. So, while some technologies will be verified in a pilot development program, others will be identified and tested. New constraints and solutions will be identified and developed in a continuous process. At the (Indian) research institutions, urea treatment has been tested in the ORP; but, at the same time, alternative technologies such as urea-molasses brick and biological treatment are developed. The key is to identify field problems of relevance to these technologies through surveys, on-farm research, and modeling using available information. Table 1 provides a listing of the most important concepts and methodologies pertaining to each phase. Some of them will be highlighted below, while others are available in the extensive body of FSR/E literature (Shaner *et al.*, 1982).

Diagram 1 A listing of five stages in FSR/E.

1 FS description and constraint identification
2 Technology identification/ design of research programs
3 Technology testing
4 Verification by Pilot Development Program
5 Extension of results

FS Description

The objective of the descriptive phase of FSR/E is to gain a better understanding of the FS, to identify possible constraints, and also to identify groups of more or less homogenous FS's for which new technologies can be developed. Such more or less homogenous groups of FS are called recommendation domains, target groups, or target regions. The crucial question is what parameters to choose for the determination of such homogenous groupings of FS, a question being reviewed by Jain and Dhaka (1993).

As an example of constraint analysis, some key factors related to the lack of adoption of treated straw are discussed in this workshop (session 4 and 6). These constraints include:
- lack of funds to buy urea;
- non-availability of straw;
- scarcity of water;
- non-availability of labour to treat straw;
- low producing animals, so output response is limited;
- cheap concentrate feed gives more economical results;
- availability of communal grazing areas.

Well-known methods to describe FS are baseline surveys, Rapid Rural Appraisals and benchmark studies. Baseline surveys describe the whole farming system in detail. Benchmark studies are more detailed, more focused, and describe all household activities but collect more detail on selected areas of attention which will be monitored to assess project impact and performance. For example, the BIOCON Project might collect more detail about the quantity and use of crop residues following the list of factors given above. The seminar paper by Rangnekar *et al.* (1993) highlights some Indian NGO experience in data collection and data processing during this stage, while the paper by Bernsten *et al.* (1983) provides details on these survey methods.

An alternative method is Rapid Rural Appraisal (RRA) or Sondeo (Khon Kaen University, 1987). These methods are geared to identify key constraints as rapidly as possible by fielding small multi-disciplinary groups of scientists who then visit farmers and other key informants. RRA focuses less on quantitative information than the benchmark or baseline surveys.

The RRA/Sondeo has the advantage of being a fast and less costly method than baseline surveys. However, the farmer techniques lack the more detailed baseline or benchmark data against which the impact of applied research and extension programs can be measured.

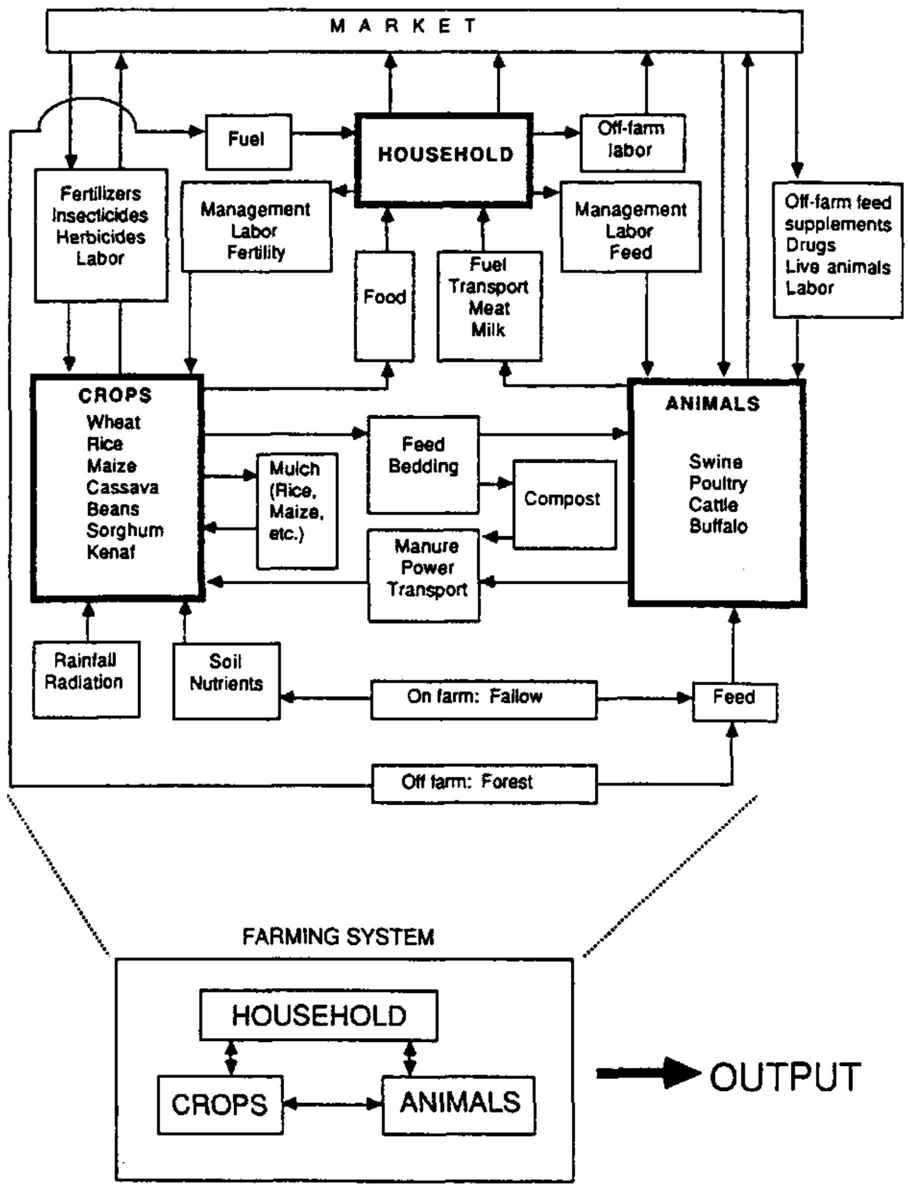
In ORP, a benchmark survey was conducted at the start of the project to find existing levels of animal and crop productivity, employment and income patterns for different categories of households. Data were also collected on the resource base, felt needs, aspirations and constraints encountered by the farmers in different farming systems. The results of the survey were utilized to formulate action programs and evaluate their impact after suitable intervals (ORP, 1988).

An effective way to start describing a FS is by a flow diagram listing the flows of inputs and output of each FS component (Figure 1). Scientists have to decide on the level of details desired and which flows need detailed analysis.

Table 1 Concepts and Methodologies in FSR.

FSR/E	Concepts	Methodologies
FS description and constraint identification	Cropping calendar Recommendation domain Representativeness Agrosystem/ecosystem Mixed FS Sampling Stratification Market Target region Target Population Key constraints	Baseline surveys Benchmark surveys RRA Sondeo Exploratory surveys Village studies Flow diagrams Focussed survey
Technology identification and design	Technology ITK (Indigenous Technical Knowledge) Technical feasibility Screening Upstream FSR	Literature review Workshops Discussions with scientist Farmers
Technology testing - on station	Resources Input/output coefficients Unit farm Input requirements Economic profitability Yield variability	Compound analysis: - Production function - Cost/benefit - Partial budget - Gross margin - ANOVA - Optimisation Whole farm analysis - Cost/benefit - Input/output - optimisation techniques - LP - Simulation modeling - Risk programming
Technology testing - on farm	Collaborating farmers Control group Opportunity cost/field price Marketing Downstream FSR Social acceptability Feedback Risk Yield gap	Scientist managed: - See above - Comparative analysis (with and without treatment or before and after) Farmer managed: - Surveys - Group discussions - WTP-analysis - Non-parametric
Pilot outreach project	Beneficiaries Input availability Institutional support/services Extension or demonstation trials Resource ownership	IRR Impact studies Policy studies Monitoring/(re)evaluation Multilocational testing
Extension	Location specificity	Monotoring/(re)evaluation Policy studies

Figure 1 The interdependent elements of farming systems and their connection with other elements within the agro-system (Source: Amir and Knipscheer, 1989).



Technology Identification/Design

Once farmers' problems are identified, solutions are sought. There might be readily available "on-the-shelf" technologies or technologies still to be developed. A technology can be defined as a management practice of producing or storing a farm product or, more simply, as a way of doing things on the farm. Where do we find new technology and how does one design a new one? Existing technologies can be found by literature review (Kherde and Rao, 1988), exploration among scientists and extension agents and last, but certainly not the least, by surveying farmers' practices. Increasingly, the value of farmers' knowledge is being realized (Chambers *et al.*, 1989).

The development of new technologies is a creative process. New ideas or notions can originate in anybody's mind, scientists and farmers alike. Processes that stimulate creative thinking are discussions, workshops and exposure to new ideas by video, film, literature, or whatever means. This creative process can be guided by helping scientists to focus on the most relevant problems by modeling. The paper by De Wit *et al.* (1993) on the economics of grain/straw breeding strategies is a good example.

In the past, the main focus of research and development has been on the quantity of output. But planners, administrators and scientists should also focus their attention on the quality aspects of milk, grain and straws in view of the emerging needs of society as well as on the most economical methods of producing milk.

Technology testing

Technology testing is really another aspect of technology design as the development of new technologies is a continuous process of (re)design and (re)evaluation. Technologies are screened according to three criteria:
1. technological feasibility;
2. economic profitability;
3. social acceptability.

The discussion of urea treatment of straw in this workshop considers all these three criteria. Lately a fourth criterion is being added:

4. sustainability, meaning what is the impact of the use of a new technology on the natural resource base of the farmer, such as the quality of the land, quality (and quantity) of water, and recycling of farm nutrients (Conway and Barbier, 1990).

Technical feasibility is generally tested by on-station research. Each discipline has a variety of analytical tools at its disposal. Analysis of variance (ANOVA) is a technique often used by biological scientists.

Economic profitability can be measured in many ways: cost-benefit analysis, partial budgeting, gross margin analysis or production response functions. The paper by Sitaramaswamy and Jain (1993) presents an overview of some of the models available for economic analysis of farming systems. Singh *et al.* (1993) present an example of usefulness of some of these methods. Critical for such economic analysis is the proper value of technical input-output coefficients obtained from on-station experiments which are not necessarily valid for on-farm conditions. For example, soil conditions, soil fertility, and pest conditions of the research stations generally lack much resemblance with real farm conditions because of previous management practices and management used on surrounding experiments. Consequently, technical feasibility has to be confirmed by on-farm experimentation, and the analysis of economic profitability should reflect these results as shown by analysis of urea-treatment of paddy straw and its feeding in session IV of this workshop. Another analytical tool is linear programming (LP). Vijayalakshmi *et al.* (1993) present an example of the application of LP for FSR/E analysis. One of the advantages of these models is the possibility of simulation: what is the impact of a change in the value of a technical input/output coefficient. If the results are markedly positive, research geared to improve such a technical input-output relationship should receive priority.

It should be noted that economic modeling can also be used in earlier stages of FSR/E; e.g., in the stage of FS description. Modeling the existing farm situation can also help the identification of constraints and their economic weights (Asian Development Bank, 1985; SEARCA, 1987). An LP model in which the existing crop and livestock production is fixed will show what constraints are the most limiting factors and what is their marginal value. Optimizing the existing farm situation with the restrictions and existing technology will serve as a good basis for comparison with the optimum farm plans using improved technology. Examples of crop-livestock models are given by Morrison *et al.* (1986).

Social acceptability is typically tested by direct communication with farmers. Farmers' perception of new technologies and of how these technologies performed in on-farm trials continuously provide essential feedback to scientists. Because this feedback often cannot be presented in a scientific format, scientists tend to exclude this information in their reports (especially when the feedback is negative!). So, most of such feedback is by word of mouth.

The disadvantage of feedback ("land-to-lab" communication) by word of mouth, is that it is easily missed by third parties. However, there are non-parametric analytical tools available by which farmers' opinions can be formatted in scientific language (Bhattacharya and Johnston, 1977). Sociology and anthropology are disciplines which tend to be familiar with such methodologies, and one may wonder if research institutes should not bolster their capacity in these disciplines. In this seminar, Rangnekar (1993) and Gahlot *et al.* (1993), highlight the importance of scientists paying more attention to farmers' perceptions.

Special Problems for On-farm Animal Research (OFAR)

On-farm research (OFAR) with animals poses problems which on-farm cropping research (which is already cumbersome) does not face. Bernsten *et al.* (1983) have highlighted these problems. Because of these problems in collecting quantitative data from OFAR, the involvement of farmers and the systematic collection of qualitative data from them becomes even more important (Amir and Knipscheer, 1989). Table 2 provides a summary of the major differences between on-farm research with crops versus animals.

Some farmers resist participating in on-farm research more strongly than others depending upon their financial position, their expectations towards the new technology, and their general attitudes toward risk. Traditional farmers are conservative and respond to new technology cautiously. However, assurances that any loss will be reimbursed and selective use of incentives often win their cooperation. Progressive farmers are looking for new opportunities and usually are willing to experiment with new technology.

Pilot Outreach Program

One of the disappointments of FSR has been the lack of adoption of new technologies even after these have been proven technically feasible, economically profitable, and socially acceptable. It is now clear that multi-disciplinary teams of scientists have the responsibility to research the extension process itself. The paper by McDermott (1987) also presents a balanced view of why the technology diffusion process often fails. Pilot outreach projects or operational research projects have been developed to deal with this problem in India, but these represent a new approach in many other countries. During a pilot outreach project, new technologies are extended while the needed institutional support services, such as input delivery, market access, and management guidance are provided. The ORP at the NDRI is an example where A.I. and veterinary services are provided as well as milk collection facilities. Farmers are provided with management recommendations in a variety of ways. During this stage new technologies are fine tuned, and effective extension and supporting mechanisms are sought. On-farm trials continue but generally have more the character of demonstrations rather than experiments. The ORP (1988) also reflects the ability of this approach to identify constraints that are important to researchers.

Table 2 Comparison of Characteristics of Crops and Livestock and Implications for On-Farm Testing.

Factor	*Situation with respect to*		*Implication for on-farm livestock research*
	Crops	Livestock	
Mobility	Stationary	Mobile	Difficult to measure and control non-experimental factors
Life cycle duration	Generally 4 months	Generally 1 year	Increases costs and likelihood of losing experimental unit
Life cycle synchronization	All units synchronized	Units seldom synchronized	Difficult to find comparable units
Multiple outputs and residues	Only grain/tuber and residues	Meat, hides, milk, manure, power	Difficult to measure/ value treatment effect
Non-market inputs and outputs	Few	Many	Difficult to value
Experimental unit size	Small, divisible	Large, divisable	Increases cost, risk to cooperator
Producer attitudes	Impersonal	Personal taboos	Difficult to cull, castrate, earmark
Management variability	Low	High	Difficult to isolate treatment effect
Observation units	Many	Few	Large statistical variability
Ownership	Individual	Often shared or inherited	Joint management
Resource attribute	Land tenure individual	Often communal land	Reduces motivation
Target audience	Individual farmer	Farm family	Increases management variability

Source: adapted from Bernsten et al. (1983) and Gryseels (1988).

Once a pilot outreach project is in place, a research institute has effectively set up what one could call a field laboratory. In such a field laboratory, on-farm trials, group discussions with farmers, constraints identification, and most other types of FSR/E studies can be conducted simultaneously. It is important, however, to let farmers know beforehand the difference between on-farm experimentation and demonstration. Urea treatment trials were conducted in ORP villages but adequate pretesting of this technology on-station was not done. Farmers believed this was a demonstration and were not aware of any possible risk of failure. As a result of possible risk, farmers did not adopt this technology in the ORP villages.

Extension

In the last two FSR/E phases described, we have emphasized the need for "lab-to-land" and "land-to-lab" mechanisms. Earlier we introduced the concept of field laboratory which may be defined as a group of farmers who collaborate with a group of scientists on a long-term basis. So, in many ways the communication described was "lab-to-fieldlab" and "fieldlab-to-lab" interaction. One of the major remaining challenges is how we transfer the benefits of the results in the pilot outreach project to the rest of the country ("field-to-land"). Institutional mandates and linkages are essential. As FSR/E proceeds, increased collaboration with extension organizations (public or non-governmental) is desirable so that in the last phase, the extension or development organization has gained the lead in the technology transfer activities. Actually, this rarely has happened, and it poses real problems.

As a summary, Table 3 indicates how the role of a research institute can change relative to the role of field oriented groups, which we have here called "Grassroots Support Organizations". Obviously, these roles can be reversed, run in parallel, or be repetitive; but, the examples are instructive.

Table 3 Role and attitude of state institutions and grassroot organisations in different phases of technology transfers

FSR/E Stage	Research Institute	GSO*
Descriptive phase recommendation domain and/or target region/population	Not yet defined	Given
Technology design/identification	Pre-conceived Scientist driven Input oriented Technical	Responsive Farmer problem solving Knowledge oriented Social
Technology testing	Mostly on station Quantitative Excluding farmers Single compound	Mostly on farm Qualitative Farmer participatory Household oriented
Extension motivation of key personnel client	Weak linkage Identification with technology Input oriented	Strong linkage Identification with

GSO* = Grassroots Support Organization.

CONCLUSIONS

FSR/E seems to be an essential component for a successful research program as the development of improved and applicable technologies is what agricultural research is all about. The FSR/E approach is critical for success of programs that are focused on the use of intermediate products which are produced and used within the same household and which are a significant linkage between the crop and animal enterprises within Indian farming systems. FSR/E can be conceptualized as a multi-phase process, where in each phase an array of methods are available to scientists. This afternoon's seminar highlights the lessons learned so far and forms a basis to guide future activities.

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FARM TYPOLOGY IN FARMING SYSTEMS RESEARCH

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SUMMARY

A review of principles and purposes of farm classifications is given, followed by a discussion of agro-ecological zoning in India. Various statistics relevant to classification of mixed farming systems and the livestock sector are then reviewed. Some income and input productivity-based systems used in other countries are reviewed as well as selected studies carried out in India based on farm size and/or animal numbers. A proposal for classification of farming systems is then presented. Cluster analysis can be used to group the key variables into a limited number of farming systems for more cost effective targeting of technology to recommendation domain. Depending on the purpose of the farm classification, the researcher should choose the classification parameters, based on physical, geographical, agroclimatic, demographic, socio-economic, farm management and extension variables.

INTRODUCTION

Mixed farming is practised in India where livestock production has been complementary to crop production since ages. In the Northern and Western regions crop production is combined with livestock rearing. In the arid regions, rearing of cattle, buffaloes, sheep, goat and camel is the most important enterprise. In the Central region comprising Madhya Pradesh, Bihar, parts of Maharashtra and Andhra Pradesh, cultivation of cereals, jute, pulses, oilseeds, sugarcane and tobacco is common. In these areas, livestock raising is popular but not economically as important as in the Northern and North-Western regions. In the Southern region, cereals, oilseeds, pulses etc. are cultivated while livestock raising on modern lines is practised only in few pockets. In the North and North-Eastern hilly region, cereals and fruit cultivation are combined with sheep or pigs.

Given the need to raise farm productivity and farm income through the selective introduction of new technologies into complex and highly variable farming conditions, new approaches are gradually evolving. In this context, there is a need to use a Farming Systems Research (FSR) approach to increase income and employment, technology generation, adaptation and diffusion according to the needs of different farming systems in the country. This general approach is set out in this workshop by Patel *et al.* (1993).

For the Farming System Research and Development approach to be effective and to justify the additional resources needed,

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available technologies must be tar ɔted to groups of farmers operating under "similar" sets of conditions where the conditions are thought to strongly influence the potential profitability of the technologies (Shaner, 1984). The combination of environmental and farmers' conditions is known as a recommendation domain (Byerlee *et al.*, 1980). Choice of an appropriate recommendation domain maximizes the likelihood that farmers within the area will react similarly to proposed changes in technologies generated by the researchers.

Many different approaches have been tried for stratification or classification of farm types, using environmental and farmers' preferences. Some of these most relevant for India are reviewed in the next section. In general, developed countries use stratification criteria based on commercial criteria related to economic status such as gross returns, net value added to land, labor and capital; fulltime vs part-time farming, or activity specialization. In developing countries, these distinctions, as noted above, are less relevant and agro-climatic conditions, cropping patterns, farm size, livestock density and productivity and feed resources must be factored in.

Infrastructure, price relationships, private and public sector support services and farmers general socio-economic conditions should also be factored into the stratification scheme based on the 1966 livestock census. Singh (1974) classified the country according to different parameters including units of (per 100 ha crop land) livestock, cattle, buffalo, draught force, milch cows and milch buffaloes. He also classified the country based on percentage of total crop area planted to fodder crops over the period 1961-1966 as well as cropping pattern zones. Muthaiah (1988) classified the country on the basis of livestock density using the 1977 livestock census as well as per capita milk production for 1985-1986.

REVIEW OF FARM CLASSIFICATION IN INDIA

Regional classification of the country

Since the inception of formal planning in India in 1951, a number of attempts have been made to categorise the country. The recent scheme for agro-climatic regional planning as developed by the Planning Commission, Government of India, New Delhi (Alagh *et al.*, 1989) divides the country into 15 resource development regions. This classification is based on physical conditions such as topography, soil type, geographical formation, rainfall, cropping patterns and development of irrigation. Each region was divided into micro-regions based on soil, temperature, rainfall and other agro-meteorological characteristics. The National Agricultural Research Project (NARP) of the Indian Council of Agricultural Research has identified 15 agroclimatic regions which were further subdivided into 120 micro agro-climatic regions (Figure 1) after taking into account rainfall patterns, temperatures, soil types and cropping patterns of each state as a unit (Saxena, 1989; Ghosh, 1991). Of particular interest to NDRI is the livestock and feed resource dimension of these classification systems.

Table 1 Density of livestock population for 1982 (heads/100 ha cropped area).

State	Cattle	Buffalo	Goat	Sheep	Total livestock
A.P.	103	68	44	59	281
Assam	190	16	49	1	272
Bihar	168	48	126	14	369
Gujarat	64	41	30	22	160
Haryana	44	63	11	14	143
H.P.	227	64	111	114	521
J & K	232	56	100	191	594
Karnataka	101	33	41	43	221
Kerala	108	14	70	*	197
M.P.	122	29	34	4	192
Maharashtra	81	20	39	13	155
Manipur	397	73	22	7	697
Meghalaya	264	14	89	13	484
Nagaland	85	5	35	*	264
Orissa	155	16	59	24	259
Punjab	47	66	10	9	139
Rajasthan	73	33	84	73	270
Sikkim	168	4	93	11	309
Tamil Nadu	172	53	87	92	417
Tripura	178	4	90	1	302
U.P.	106	64	39	9	230
West Bengal	224	14	156	19	424
All India	111	40	55	28	242

* negligible.

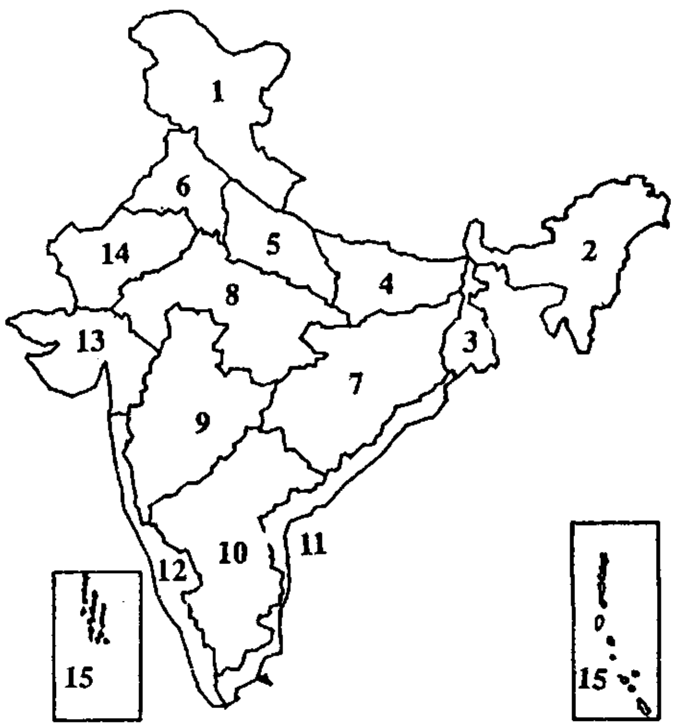
Livestock distribution in India

Livestock and dairying play a dominant role in the Indian economy and contributes nearly 25 per cent of the total value of the combined output from agriculture and animal husbandry at 1987-1988 prices (Malik, 1990). Milk is the second largest agricultural crop next to rice (Aneja, 1990). There is a wide variation in livestock density in different states of India.

Table 1 shows that livestock density was greatest in Manipur followed by Jammu and Kashmir, Himachal Pradesh, Meghalaya. Haryana and Punjab had the lowest livestock density which may be attributed to higher intensity of cropping and high culling rate of animals. This does not adjust for livestock units, however, such areas where sheep and goats predominate are over-represented. Similar observations were made with respect to density of cattle. On the other hand, Punjab and Haryana had relatively high concentration of buffaloes per hectare of cropped area. This may be attributed to concentration of better breeds of buffaloes in this region and preference for black animals (=buffalo) due to high fat content in its milk. States with the highest livestock numbers typically had limited area of crop land

and surplus land for communal grazing, though the availability of land for common grazing is diminishing drastically (Jodha, 1986).

Figure 1 Fifteen Agro-Climatic Regions of Planning Commission.



1. Western Himalayan Region
2. Eastern Himalayan Region
3. Lower Gangetic Plain Region
4. Middle Gangetic Plain Region
5. Upper Gangetic Plain Region
6. Trans-Gangetic Plain Region
7. Eastern Plateau & Hills Region
8. Central Plateau & Hills Region
9. Western Plateau & Hills Region
10. Southern Plateau & Hills Region
11. East Coast Plains & Hills Region
12. West Coast Plains & Ghats Region
13. Gujrat Plains & Hills Region
14. Western Dry Region
15. Island Region

Source: Ghosh (1991)

Cow and buffalo productivity

The productivity of cows and buffaloes as measured by yield per day of lactation for some major states for 1986-1987 (Basuthakur and Malik, 1989) is given in Table 2. The estimated daily milk yield per cow as well as per buffalo was highest in Haryana and lowest in Orissa. The highest milk yield observed in Haryana could be due to concentration of better breeds of cows and buffaloes as well as higher availability of feeds and fodder in the state.

Table 2. Productivity of milch cow and buffalo (1986 - 1987).

State	Cow		Buffalo	
	Animals in milk (%)	Milk yield (kg/day/animal in milk)	Animals in milk (%)	Milk yield (kg/day/animal in milk)
Assam	NA	NA	63.03	1.92
Bihar	37.93	1.76	37.82	3.62
Gujarat	54.28	2.60	63.10	3.56
Haryana	64.73	3.39	68.95	4.58
H.P.	53.99	1.50	58.21	3.15
Karnataka	51.88	1.72	55.12	2.27
Kerala	63.16	3.11	62.88	2.83
M.P.	45.00	1.38	60.00	2.54
Maharashtra	44.07	1.30	60.59	2.55
Meghalaya	NA	NA	54.55	2.07
Orissa	45.26	0.51	49.22	1.29
Rajasthan	NA	2.72	NA	3.85
Sikkim	NA	2.03	NA	NA
Tamil Nadu	56.68	3.02	60.20	3.54
U.P.	53.74	1.91	62.38	3.25
West Bengal	NA	1.37	NA	3.80
A & N Islands	NA	2.67	NA	2.83
Lakshadweep	33.33	2.45	NA	NA
Pondicherry	57.14	3.12	NA	NA
Delhi	NA	NA	78.07	5.89

Milk availability

The availability of milk in the country during 1987-1988 was estimated to be 160 g per capita per day (Jain and Sharma, 1990) as shown in Table 3. It was highest in Punjab followed by Haryana, Himachal Pradesh, Rajasthan and Gujarat. The higher availability of milk in Northern and Western states is due to high productivity of cows and buffaloes in these states. The Southern, Eastern and North-Eastern states had poor availability of milk which was even lower than the national average.

Area under fodder crops and grazing lands

The area under fodder crops relative to total cropped area was 4.4 per cent at the national level out of which only about 22 per cent was irrigated (Table 4). The highest relative area under fodder crops was observed in Rajasthan followed by Haryana,

Table 3 Milk production and per capita milk availability for 1987-1988.

State	Milk production (1000 tonnes/yr)	Milk availability (g/capita/day)
A.P.	2980	135
Assam	613	73
Bihar	2850	98
Gujarat	2997	213
Haryana	2498	448
H.P.	478	272
J & K	428	170
Karnataka	2310	149
Kerala	1264	122
M.P.	3220	148
Maharashtra	2657	102
Manipur	79	130
Meghalaya	49	85
Nagaland	5	13
Orissa	408	38
Punjab	4312	625
Rajasthan	4000	270
Sikkim	25	169
Tamil Nadu	3109	159
Tripura	26	30
U.P.	8316	176
West Bengal	2664	118
All India	45510	160

Table 4 Area under fodder crops, permanent pastures and other grazing lands.

State	Total sown area under all crops (1000 ha)	Area Under Fodder Crops			Area under fodder crops (% of total sown area)	
		Irrigated (1000 ha)	Total (1000 ha)	%		
A.P.	12100	8	176	4.55	1.45	7.28
Assam	3794	-	3	-	0.08	-
Bihar	10517	-	14	-	0.13	1.50
Gujarat	9683	113	902	12.53	9.32	8.75
Haryana	5601	295	636	46.38	11.36	0.50
Himachal Pradesh	974	3	8	37.50	0.82	-
Jammu and Kashmir	1030	21	31	67.70	3.01	-
Karnataka	11146	8	78	10.26	0.70	10.44
Kerala	2866	-	2	-	0.07	0.14
Madhya Pradesh	23016	25	892	2.80	3.88	12.20
Maharashtra	20537	NA	801	NA	3.90	7.59
Manipur	183	-	-	-	-	-
Meghalaya	212	-	-	-	-	-
Nagaland	197	-	-	-	-	-
Orissa	9259	-	-	-	-	6.67
Punjab	7158	620	722	85.87	10.09	0.06
Rajasthan	18137	252	2566	9.82	14.15	10.15
Sikkim	134	-	-	-	-	-
Tamil Nadu	6819	7	109	6.42	1.60	2.17
Tripura	423	-	-	-	-	-
Uttar Pradesh	24981	360	861	41.81	3.45	1.41
West Bengal	7987	-	3	-	0.04	0.09
All India	177334	1718	7820	21.97	4.41	6.75

Punjab and Gujarat. In the remaining states, it was below the national average. The highest fodder area observed in Rajasthan could be attributed to poor irrigation facilities, low cropping intensity and fallow land being used for growing fodder crops. The irrigated fodder area was observed to be relatively more in Punjab (86%), Haryana (46%) and Uttar Pradesh (42%) compared with the national average (22%). The availability of permanent pastures and grazing lands differ widely between states (Table 4). Madhya Pradesh had the highest availability of such lands followed by Karnataka, Rajasthan and Gujarat.

Feeds and fodder availability

The production of livestock, particularly that of bovines, depends upon the availability and quality of feed and fodder. Availability of cultivated green fodder (fresh matter) for various states of India was estimated by using the yield at 50 tons fresh matter/ha for irrigated land and 25 tons fresh matter/ha for unirrigated land. Dry fodder availability was estimated as the total of crop residues of major cereal crops and by-products of pulses using the straw : grain ratio for these crops. Oilseed cake availability was estimated from the production of oilseeds using the percentage yield of cake in oil seeds. The information regarding the estimated yield of fodder crop, straw : grain ratio and per cent yield of cake was obtained from Mishra and Sharma (1987). The estimated per head availability of feeds and fodder (kg/head/day) was calculated by dividing the total availability by the estimated bovine population.

The daily per head feed and fodder availability at the national level during 1988-1989 was 2.36 kg green fodder, 2.58 kg dry fodder and 0.15 kg oilseed cake (Table 5). Among various states, it was highest in Punjab followed by Haryana, Rajasthan and Gujarat. The higher availability of feeds and fodder in Punjab and Haryana may be due to higher proportionate area under fodder crops, better irrigation facilities and more intensive cropping while in Rajasthan it could be due to fallow land left because of poor irrigation facilities, lack of alternative crop production activities and a relatively large area of irrigated fodder crops. Feed and fodder availability was lowest in Bihar, Orissa and West Bengal.

All these figures illustrate the wide variability in livestock density, productivity of cows and buffaloes, feeds and fodder availability, milk production and milk availability in different states/regions of the country. Such variations are caused by agro-climatic conditions, uneven irigation facilities, different livestock breeds, crop intensity, management practices and marketing facilities. Hence, there is a need to stratify various farming sub-systems and identify suitable sub-systems for different regions, in order to maximize the targeting of research findings as noted above.

Table 5 Feeds and fodder availability for bovines during 1988-1989 (grams per head per day).

State	Green fodder	Sugarcane top	Dry fodder	Oilseed cakes	Total bran
A.P.	540	137	2370	153	56
Assam	24	66	1342	33	41
Bihar	44	69	2099	8	60
Gujarat	5633	175	1992	581	28
Haryana	10356	293	6162	458	195
H.P.	265	-	1874	3	33
J & K	1151	-	1904	14	36
Karnataka	395	337	2323	247	19
Kerala	38	44	1162	3	36
M.P.	1830	19	1901	132	38
Maharashtra	2562	326	2732	252	25
Manipur	-	22	1142	3	33
Meghalaya	-	3	953	30	22
Nagaland	-	181	3268	55	82
Orissa	NA	58	2490	69	44
Punjab	11137	184	8490	666	304
Rajasthan	9134	8	2143	203	30
Sikkim	-	-	-	-	-
Tamil Nadu	581	477	2345	173	49
Tripura	-	25	2422	16	74
U.P.	1910	559	3247	41	101
West Bengal	11	17	2455	33	74
All India average	2360	203	2581	156	66

* refers to 1985-1986.

Farm size as parameter for classification

Several farm size classifications have been suggested based on farm and herd size. Most researchers have used cumulative cube root method of stratification (Singh, 1975) for farm size classification and have either done pre-stratification or post-stratification of farms. The categorisation of farms has been different between research studies conducted in distinct regions. The categorisation was a function of the researchers specific needs. A review of several studies using farm and herd sizes for categorisation of farms is given below. Farm size classification are region specific and depend on the sub-systems under consideration, e.g. like crop, livestock, poultry, or sericulture. Many important parameters have not been considered while classifying the farms into different categories, such as price relationships, support services and infrastructure, availability of off-farm employment opportunities and levels of crop and livestock technologies being employed.

Generalized classifications for the whole country are given by National Commission on Agriculture (1976) and a classification for specific areas is suggested by Patel *et al.* (1982) (Table 6).

Sharma (1982) used a classification suggested by NCA for farm size categories. The herd size criteria used for categorisation of dairy farms possessing cross-bred milch animals are given in Table 7.

Table 6 Classification of farms according to size of operational holding (ha)

Class	(NCA, 1976)	(Patel *et al.*, 1982)
Marginal holding	< 1	< 1
Small holding	1 - 2	1.1 - 2.0
Semi-medium holding	2 - 4	2.1 - 4.0
Medium holding	4 - 10	4.1 - 8.0
Large holding	> 10	> 8.0

Note: see text for reasons of differences

Table 7 Classification of farms in India according to herd size

Category	Herd size	
	Sharma (1982)*	Sharma (1984)**
Small	1 Cow	1 - 3 cows
Medium	2 - 3 Cows	4 - 9 cows
Large	> 3 Cows	> 10 cows

* From a study of Economic Appraisal of Intensive Cattle Development Project (ICDP), Karnal;
** From a study on economics of cross-bred cattle in Bangalore City.

Singh (1984), classified the farmers into four farm categories in Haryana state (landless, small, medium, large). The landless labourers were those having no landbase, and the other three groups were categorised by arranging the operational holdings of the farm households in ascending order and then using cumulative cube root method of stratification (see Table 8). Landless labourers are thus not considered in Table 8.

Table 8 Classification of farms according to farm size in Haryana

Sl. No.	Zone	Farm size (ha)		
		Small	Medium	Large
I	High milk - Paddy, Wheat (North-East)	0.01 - 1.70	1.71 - 4.32	> 4.33
II	High milk - Bajra/Jowar, Wheat (South-East)	0.01 - 1.97	1.98 - 4.58	> 4.59
III	Low milk - Cotton/Bajra, Wheat/Gram (North-West)	0.01 - 2.09	2.10 - 5.39	> 5.40
IV	Low milk - Bajra, Gram (South-West)	0.01 - 2.28	2.29 - 5.00	> 5.01
V	Medium milk - Maize, Wheat (North or Submountainous)	0.01 - 1.42	1.43 - 3.34	> 3.35

Source: Singh (1984).

The farm holdings were further classified into commercial and non-commercial milk producers. Commercial milk producers were those selling over 50 per cent of the milk produced while non-commercial milk producers were those consuming over 50 per cent of the milk produced in the household.

Gill (1981) classified the farm holdings into three categories based on data from Punjab. His classification was different for different zones in Punjab and was also based on the cumulative cube root method of stratification (see Table 9).

Before making the final selection, the farm holdings in each category were classified into commercial and non-commercial milk producers based on per cent milk sold as noted above (Gill, 1981).

Vijayalakshmi (1985) while conducting a study on optimum crop and livestock production decisions under uncertainty in Bangalore district (rural) classified cultivable farm holdings possessed by 240 sample cattle keepers by employing cumulative cube root method of stratification (see Table 10).

Table 9 Classification of farms according to farm size Punjab

Sl. No.	Zone	Small	Medium	Large
		ha		
I	High milk - Paddy, Maize (Central)	< 2.71	2.71 - 5.23	> 5.23
II	Medium milk - Paddy, Maize (Central)	< 3.14	3.14 - 6.36	> 6.36
III	Medium milk - Paddy, Maize (Submountainous)	< 2.50	2.50 - 4.76	> 4.76
IV	Low milk - Cotton (Southern)	< 4.55	4.55 - 10.06	> 10.06

Source: Gill (1981)

Table 10 Classification of farms according to farm and herd size in Bangalore District

Category	Farm size (ha)	Herd size (milch cows)
Marginal Farm	Up to 1.74	-
Small Farm	1.75 to 2.55	1 - 2
Medium Farm	2.55 to 6.43	3 - 4
Large Farm	> 6.43 ha	> 5

Source: Vijayalakshmi (1985).

All these studies suggest that using only farm size or herd size as the criteria for categorising farmers and cattle keepers is inadequate. This is probably still a simplification, because these studies do not consider other parameters like irrigation, soil type, cropping intensity, cropping pattern, use of high yielding crop varieties (HYV), crop rotation, level of inputs used (seed, fertiliser etc.), resource infrastructure, marketing facility, etc. Even when only dairy farming is considered, herd size cannot be the sole criteria of classification. One should also consider other parameters like whether the dairy unit is commercial or non-commercial, type of bovines maintained, i.e., local, cross-bred cows and buffaloes, availability of feeds and fodder, market infrastructure etc. Poultry farming should not only take the number of birds maintained but also availability of feeds and marketing facility. Moreover, attention could be given to socio-economic variables including family size, social status, income, education, management skill, etc. In mixed farming, therefore, proper weight should be given to each type of farming activity. Thus farm categorisation not only depends on farm size and other parameters but also on the purpose for which it is to be done. The ultimate objective should be to create a grouping of homogeneous farms to better focus the research, development or extension efforts devoted to rural development.

REVIEW OF OTHER METHODOLOGY FOR CLASSIFICATION

Criteria for farming systems classification are usually location specific (Menz and Knipscheer, 1981). Given limited resource availability, Farming Systems Research must find cost-effective methods for coping with the problem of how to describe diversity. One method is to identify parameters of environments and of existing systems which are relevant for guiding the formulation of new systems. As the number of parameters to be included in a classification scheme increases, each location is described more realistically. However, this realism is at the expense of an increase in the total number of possible systems that may be described. It is not possible to specify the optimal number of systems into which a research recommendation domain should be divided. Beyond a certain number, further subdivision resulting from inclusion of additional parameters becomes self-defeating. The problem of location specificity in Farming Systems Research can be circumvented to some extent by an appropriate choice of suitable number of important parameters to be included in a classification.

Additional methodologies for classification of farming systems have been proposed, such as cluster analysis and the study of differences between gross returns and non-factor inputs like expenses incurred on fertiliser, seed, pesticide, depreciation, etc. or factor inputs for land, labour and capital.

Cluster analysis was used by Hardiman *et al*. (1990) employing the "average linkage method" for the identification and classification of farming systems in Quingyang county on the Loess Plateau of Central North China. Data from 26 townships describing socio-agricultural parameters of farm households were standardised and a Pearson correlation matrix was constructed. Parameters with the highest correlation coefficients and largest standard deviations were selected for cluster analysis. A total of 29 socio-agricultural parameters for each township were selected, including administration and population; climatic data; cultivated areas of valley, slope and table-land; livestock numbers; draught power; crop yields; and total labour force. The data were converted to units per household, proportionate area of each land type, livestock number per unit area, and draught power per unit area for each township. A Pearson correlation matrix was created and significantly correlated directly dependent variables were identified e.g., rainfall and wheat yield. These variables were then standardised and further analysed for standard deviation. Only those variables that had a large standard deviation were considered important in defining different farming systems. Out of a total of 29 variables analysed, seven were selected for cluster analysis. Standardised data for these attributes were processed by cluster analysis using the average linkage method. Three major farming systems comprising three, one and three sub systems were created for 24 townships. Topography was found to be a principal factor in characterising the major farming systems which were broadly defined as:

FS I - Hilly slope lands (12 townships),
FS II - Hilly slope lands and valleys (2 townships),
FS III - Southern tablelands (10 townships).

Shankariah *et al.* (1980) listed the variables which should be considered for target grouping of farmers for adopter categories which can be made applicable to most developing and developed country situations. They suggest that the categorisation of the target groups should use variables that accelerate the development of agriculture and the people, to be classified into four major classes:

- geographic variables,
- demographic variables,
- personality variables,
- farm management variables.

The geographic variables include states, regions, districts, towns, cities or neighbourhoods. Demographic variables include age, family size, income, education, social class, occupation etc. Personality variables considered were values, motivations, social participation, extent of information exposure etc. Farm management variables are unique to the farming system, mainly independent of demographic or personality variables, and help to understand the constraints at the farm level or problems to implement technological programs. Farm management variables include size of farm operation, type of farm ownership, farm specialisation, level of mechanization, stage of development, yield per hectare, yield per cow etc.

For example in most countries the objectives are to increase production and improve the equity among the farming community. In that case, farm size, social status, and level of farm development can all be used to categorise the target groups. However, these factors may not be of much help in targeting specific technologies to recommendation domains. Farm size is easy to measure and usually related to income and level of production within a given agro-ecological zone. Social status and level of farm development provide other important dimensions for categorisation.

Röling (1989) describes one of the methods developed by CIMMYT in Nairobi, using crop combinations, type of draught power used, farm sizes, off farm employment etc. Another method pioneered by the Institute for Development Studies in Nairobi, Kenya (Röling, 1989) can be used for rapid target group and recommendation domain identification. This method divides the district into roughly homogeneous areas in terms of farm type, relief, rainfall Figures, cropping pattern etc. For each zone, one determines the innovations that have been adopted by farmers in the past ten years. Based on the information from field workers, one tries to assess the percentages of farmers who have adopted each innovation.

Bartelink and Kamil (1989) suggest typological criteria such as geographic situation, household organisation, source of income and occupation. Structural criteria include parameters like age, sex, family status, educational level, ethnic origin, tribe, caste, religion, language and level of income. The functional criteria includes primary target category viz., those who profit directly from a program e.g., farmers, malnourished children etc., subsidiary target category viz., those who profit indirectly from a program e.g., farm labourer, transport companies; implementary target category e.g., those through whom the measures are carried out e.g., politicians, researchers, extension agents, ministry employees, health educators and teachers.

RECOMMENDATIONS AND A SUGGESTED PROCEDURE

To more effectively plan and target agricultural research, one needs to define farming systems based on specific resource characteristics and productivity levels leading to stratification based on the principles of recommendation domains. Better definitions will assist in the allocation of research resources and in the design of on-farm testing programs targeted to specific types of farming systems. The classification of farms is region and purpose dependent and should be based on socio-economic variables focusing on specific farm characteristics.

Some key variables for adoption of technologies developed by NDRI include:
- milk animal numbers and productivity;
- per cent of area under green fodder crops, and the percentage of this area that is irrigated;
- availability of permanent pasture and grazing land, particularly communal grazing lands;
- availability of green fodder, dry fodder and oilseed cakes and the percentage of dry fodder compared to total feed available on an energy and protein basis;
- supply of urea and water for straw treatment;
- labour availability for fibrous crop residue treatment, including cost and seasonality;

- milk marketing, including prices and proportion sold;
- farmer preferences for straws, and indigenous knowledge about different varieties grown under rainfed versus irrigated conditions, level of fertilizer, crop duration, etc;
- availability, use and feeding of draught animals.

CONCLUSIONS

A large country like India is very diverse with regard to land use pattern, cropping system and livestock keeping. When our aim is to increase net returns of farmers, there is a need to do region-specific research and extension. This can be based on a FSR/E approach. Several research workers have categorized the country into various agro-climatic regions since the start of planning in the country. But the suitability of macro-regions from a farming system perspective, particularly livestock farming combined with crop farming, needs to be reconsidered. Parameters like livestock density, productivity of milch cattle and buffaloes, milk availability, feeds and fodder availability, resource infrastructure, marketing etc. have not been considered in the earlier classification and need to be included. Socio-economic parameters like family size, social status, income, education, customs and traditions, management skill also vary considerably and, therefore, need to be considered as well. Cluster analysis can be used to classify the country into different macro-regions or recommendation domains. Depending on the purpose of the classification, the objective should be to include one or more of the parameters based on, physical, geographical, agroclimatic, demographic, socio-economic and farm management and extension variables. For purposes of targeting technologies developed by the various NDRI institutes and cooperating institutions, only partial reliance can be placed on existing national and state data. Zoning and stratification on a regional or district basis will be needed. This will require synthesis of existing bio-physical and farm survey data with additional data obtained from Rapid Rural Appraisals and specialized surveys. This will better focus stratification of market price relationships and animal production linked to types and availabilities of crop residues. The recent report by Kelley *et al.* (1991) provides some clues as data required for sorghum and millet straws.

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THE ROLE AND TYPE OF MODELS IN FARMING SYSTEMS RESEARCH

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SUMMARY

Analysis of mixed farming systems typically requires a set of economic tools that can account for interactions between the farm household, crop sector, livestock sector, joint use of resources, use of by-products and market transactions. This paper reviews the various types of economic models that are available for use in these situations and the general characteristics of each. A plea is made to make the models more realistic in the biological components and to better represent bioeconomic, rather than strictly economic, models.

INTRODUCTION

The purpose of model building is to improve understanding of systems in order to manipulate them, to repair, to improve and to construct improved systems.

A good model abstracts from unnecessary details for the purpose of solving the problem at hand and has sufficient detail as far as the core of the problem is concerned. An attempt to trace the use and evolution of models of agricultural systems is made. A broad classification of the models on the basis of the technique as well as the function is given for a) statistical/ econometric models, b) optimisation models and c) simulation models.

In many situations the use of the models was to tackle a specific problem in isolation, e.g. to assess the relative importance and contribution of a particular factor to the overall performance, or to choose an alternative from several possible courses of action at a particular level of operation of any sub-system so as to optimise a set objective for the overall system.

To provide appropriate management decision support to the researcher and farmer, modeling of the whole farm enterprise, using systems approach with bioeconomic models covering the biological and economic factors is a research imperative. The role of analytical tools and techniques and the importance of models in structuring the problems of Farming Systems, integrating the various sub-systems into a whole, and their contributions in improving the performance of the system is now demonstrated through examples.

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DEFINITION AND APPROACH

A farming system is a unique and reasonably stable arrangement of farming enterprises that a household manages according to well-defined practices in response to physical, biological and socio-economic factors and in accordance with household goals, preferences and resources (Van Der Veen, 1986). All of the above factors influence the technology adopted and production and marketing methods used by the household and the output that is achieved.

According to Shaner *et al.* (1982) and Van der Veen (1986), FSR is an approach to agricultural research and development that:
- views the whole farm as a system, focusses on the inter-dependencies of the components under the control of members of the farm household and on the interaction of these components with physical, biological and socio-economic factors not under the household's control;
- aims at enhancing the efficiency of the farming system by improving the focus of agricultural research in order to generate and test better technology .

Commonly recognized stages for development of new technologies in Farming Systems Research are explained by Patel *et al.* (1993) and include:
- description and constraint analysis;
- technology identification/design;
- testing and verification by pilot development programs;
- extension of results.

The first two stages involve the study of the existing system in respect of the enterprises involved, production system followed, the levels of resource use, technology adoption in order to assess the technological needs of farmers for enhancement of productivity and improvement of the farming system. This requires the economic evaluation of alternative new technologies and implications of their introduction to the overall system performance keeping in view the interdependencies of the various sectors like crop enterprise and dairy enterprise and their supplementary and complementary nature in the whole-farm. Various household objectives, in addition to profit, should be considered.

DATA COLLECTION AND MODEL VALIDATION

The type and methods of collection of data cannot be independent of the analysis to which it is going to be subjected to, and the models that are going to be formulated in order to predict or extrapolate the observed phenomena. Statistical theory insists on the interdependence between the way in which data are collected and the methods of analysis. The methods of collection define the valid methods of analysis which may be employed. Alternatively if we wish to use particular methods of analysis or estimation, we have to ensure that appropriate methods of data collection heve been used. Thus the knowledge of the target population, or the population for which the output of the analysis or model is relevant, the constraints of such a sampling frame, appropriate methods of sampling and the several variables on which the information is collected and their interrelationship is essential before data collection commences. Model validation is essentially concerned with the testing of the hypothesis represented by the model and its assumptions. This testing assumes that it is possible to make predictions from the model which are capable of direct verification.

FARM MANAGEMENT DECISIONS

Managing a family farm entails several decisions at various levels, viz., strategic ('What' aspects of the enterprise) technical ('How' aspects) and operational ('Execution' aspects). Strategic decisions are done less frequently and refer to enterprise selection and optimal combination of resources. But these strategic decisions are of crucial importance due to their long range consequences. To achieve the goals/targets set at the stage of strategic decision making there could be several alternative ways and means to adopt what is a tactical decision. For example, if to limit the rate of growth of population to a certain pre-determined number is a strategic decision; to recommend the appropriate technology to a given segment of the population, keeping in view the socio-economic background and the value systems of the target population is a tactical decision. Tactical decisions pertain to the economic comparisons of alternative technologies available for implementation of the decisions taken at the strategic levels. Operational decisions relate to the tasks of routine nature. All the above decisions are subject to the availability of information and appropriate techniques.

MODELS AND THEIR EVALUATION

The choice of an appropriate technique/model assumes importance in the context of complex managerial decision-making situations in the farming systems. A model can be defined as an abstraction and simplification of the real world, specified so as to capture the principal interactions and the behaviour of the system under study and capable of experimental manipulation in order to project the consequences of change in the determinants of the system behaviour. Formulation of any model is to be made in the light of the objectives to be met, the relevance of the assumptions and the applications. However a formulated model needs to be validated before being put to use. In the face of changing decision scenarios in the farming system several techniques/models have evolved. These models range from primitive farm management techniques to the most recent holistic models.

FARM MANAGEMENT TOOLS

Traditional farm management methods provide techniques that help the farmer make decisions with regard to the optimum levels of inputs and outputs by establishing mathematical relationships between inputs and outputs through production function analysis with techniques like partial budgeting, break-even analysis etc. Statistical and econometric models assess the relative importance and contribution of the different factors to the overall performance of the farming system, to enable manipulation and regulation of the driving variables and to adopt rational decision making in the face of uncontrollable environmental factors. This procedure however takes into account one enterprise at a time and ignores the interdependencies of the different enterprises. Such models serve a limited purpose of providing decision support, caused by uncertainties about new technologies, new enterprise combinations, weather, price variations and other stochastic factors.

OPTIMISATION TECHNIQUES

With the advent of Operations Research techniques and their proven utility in tackling many type of managerial decision situations in industry, inroads were laid to employ these techniques in the farm management decisions, by suitably tailoring the farming system problem into one of Operations Research models. Optimization is done mainly through Linear Programming and its variants. In essence, optimizing is the same as choosing. One chooses a decision which optimizes his objective function. Farming as it has so often been stated is a game against and/ or with nature. Nature is not an antagonist in that it is indifferent to the strategies adopted by the farmer and so the farmer's normatively optimal strategy is to select that strategy which maximizes his objective function.

Linear Programming (LP) models were used by many workers both inside and outside India mainly for working out optimal farm plans with resource constraints. Least cost rations for animals and optimal plans for crop and livestock integration are examples. LP models where the net return/income as an objective function, with labour hiring as one of the activities often serve the purpose of accomplishing the dual objective of maximising income and employment potential through an LP model. During the 1960's, LP models were built around the short run objective of increasing the efficiency of resource use. During the 1970's LP models were extended to study the critical inputs like capital and land at varying levels. Parametric models with variable price programming and variable resource programming followed. Mixed integer programming models were introduced. Large numbers of studies were conducted at Agricultural Universities in all the states of India to work out the optimal plans for the respective areas to meet the local requirements, with the feasible alternative enterprises under specific resource constraints.

Studies with LP models in countries other than India generally consider labour, capital and management as important constraints for drawing optimal plans. In India land and capital are often the main constraints. Also dairying was assigned the role of supplementing farm incomes. The valuable findings of the studies in India centre around the fact that dairy animals in a mixed farm economy not only increased productivity of the farm but also enhanced farm employment and income.

However, all the initial studies highlighted the common limitation of assuming risk neutrality in the farm activities which resulted in fragmentary plans appropriate only for short time horizons and stable farm plans could not be attained. To account for these deficiencies in these models, incorporation of risk in the form of a measure of variance were introduced (Hazell, 1971) for the Minimization Of Total Absolute Deviations (MOTAD). Even after accounting for risk, the MOTAD model is static in nature, and meets the needs of decision making at a point of time. Decision making in agriculture realistically operates in a multiperiod environment in which production and marketing conditions, investment opportunities and consumption preferences are constantly changing over time. Resource allocation decisions made at one point in time necessarily affect farm operations for months or even years ahead. Optimal resource allocation must therefore be decided not in a static but in a multi-period setting. Thus the need for the introduction of Multi-period Linear Programming models. A review of various types of models is given in Table 1. Other optimization models used in farming decision support are dynamic programming models for replacement decisions, stochastic programming to accommodate uncertainties, non-linear and quadratic programming models to take care of the non-linear nature of objective functions, and constraints in certain situations. An elaborated review of model applications at the whole farm level is given in Bywater (1990).

None of the optimization models available in operations research adequately describe the system, even though they help the agricultural extension worker in providing an easy and cheap aid for decision making and recommending technology packages. Simulation models which describe the real world farming systems to the satisfaction of all concerned biologists, economists, social scientists are extremely difficult to optimize, or to be tackled with conventional optimizing techniques. Basically, a different approach is needed to study the systems with a view to modify and improve their productivity and performance with a needed intervention in the selected component of the system. In other words holistic approach or systems approach is needed to study and improve farming systems.

Having identified the various components, sub-systems and their interdependencies there are two alternative strategies to be used in total system model development:
- top-down,
- bottom-up modeling approaches.

Table 1 Review of optimisation models

Purpose	Input variables	Source
1. To determine optimum combination of cattle, sheep, mohair goat and deer to maintain balance of grass, forbs and shrubs in order to maximise economic returns	4 variables and 6 constraints	Van Dyne and Rebman (1967)
1. To develop optimal farm plans through positive interaction between crop and livestock enterprises for dryland crop-livestock farm	1. Wheat 2. Legume based pasture 3. Leguminous crop 4. Livestock	Morrison et al. (1986)
1. To evaluate the technological changes in range/livestock components 2. To determine the optimum number of cattle, sheep and goats and under area different crops 3. To determine the quality of supplemental feeds to be purchased	1. Land available for crops 2. Family and hired labour 3. Subsistence consumption needs 4. Capital 5. Number of cattle, sheep and goats	Nestor Gutierrez-Aleman et al. (1986)
1. To develop optimal feeding plans for cross-bred cattle with different body weights and milk productions under different price situations	Feed ingredients, price, minimum levels of DCP, TDN, Ca and P	Sharma (1984)
1. To develop optimal farm production plans and the risk efficient plans for cross-bred cattle	1. Crops, dairy and sericulture activities 2. Labour hiring activities 3. Bullock hiring activities 4. Capital borrowing activity 5. Ragi straw buying activity	Vijayalakshimi (1985)
1. To develop optimum crop and dairy plans for various categories	1. Crop and dairy activities 2. Capital 3. Labour 4. Levels of technology	Saini (1982)

The top-down modeling approach starts with a definition of objectives which dictates an overall system model. This model is continually improved by changing its structure in an organised stepwise manner, introducing more and more state variables and driving variables and increasing the complexity with more complex relationships among the variables so as to meet the objectives.

The bottom-up approach starts with isolated and independent complex process models and couples these process models into subsystems and the subsystems eventually into a system.

REPRESENTATIVE FARM MODELS

Individual farms and farm enterprises are characterized by the values taken for many factors such as soil, irrigation capital and labour. The variation in only a few of these makes each farm unique. By the same token some farms have features similar to other farms. The construction of representative farm models involves two stages; first the grouping of similar farms and secondly to construct a model typical of each group. Criteria upon which to base suitable classification framework to permit grouping of farms has been a source of discussion in various forums (Jain and Dhaka, 1993). All groupings must be related to the structure, the operational efficiency, and the developmental possibilities of farms. Provided factors can be isolated which represent suitable criteria for classification and provided these data are easily accessible for all farms in the relevant population, a number of algorithms have been established which permit clusters of farms to be produced related to these factors. However farm, and farm enterprise systems do not fall into obvious clusters as some biological populations do, because the population of farms represents a continuum of change. The function of clustering mechanism then, is to locate relatively dense areas in a continuum, and to do this cluster analysis technique is employed. Having defined clusters of similar farms it may be possible to decide that one farm in a cluster is able to represent the rest or some synthesised mean farm for the cluster may be devised. A simulation or optimization model can be built for the representative farm. Table 2 reviews some simulation studies of interest.

Table 2 Review of simulation models

Purpose(s)	Input variables	Source
1. To aid farmers in planning the farm operations 2. To analyse the effect of different calving systems on net farm income	1. Forage harvesting systems 2. Date of harvesting 3. Wheather pattern 4. Method of grain feeding 5. Size of herd	Cloud et al. (1968)
1. To examine the management strategy for crop use and animal production	7 state variables 4 driving variables 42 parameters and 22 processes	Arnold and Galbraith (1974)
1. To study the relationship between feed supply and livestock performance 2. To generate data on animal's feed intake, requirements according to production, reproduction, herd mortality events	1. Crops and their products and by-products; animal species and their products and by-products; grazing system 2. Nine animal classes of different age groups and 15 different feeds both purchased as well as home produced 3. Feed characteristics (type, amount and quality of feed) and animal characteristics, genetic potential for growth, milk production, traction characteristics	Hermans (19??)

SOFT SYSTEMS METHODOLOGY

The systems approach provides a means to formulate a unified methodology of conceptualisation of research to solve complex problems which cannot be solved through a reductionistic approach. The problems, according to the complexity involved may be arranged in a spectrum ranging between hard at one end and soft at the other (Checkland, 1985; Spedding, 1987). The hard problem is one which is completely structured and for which a tangible solution can be worked out by designing an appropriate system and optimizing its output after evaluating the alternate means through powerful mathematical techniques supported by computer software.

Alternatively, soft systems are fuzzy and unstructured. The goals and objectives in some cases cannot be well defined, the process of expressing concern itself may be difficult and imprecise due to the involvement of subjective judgements. The methodology for solving such problems is more complex and consisting of some stages as:
(1) The problem situation unstructured
(2) The problem situation expressed
(3) Root definitions of relevent systems
(4) Conceptual models
(5) Comparison of (4) with (2)
(6) Feasible and desirable changes
(7) Action to improve the problem situation.

The stages 1 and 2 are concerned with the perception of the problem situation and the expression of the concerns. This is done by viewing as widely as possible, all the relevant consideration or world views about the problem situations. The technique for accomplishing this is called 'mind-mapping', 'dendrogramming', or 'coralling'. Based on the information culled out from stages 1 and 2, a carefully phased, explicit nature of some systems, which are relevant to the problem situation, and which will be subsequently seen to improve the situation is prepared in stage 3. This is called root definition which spells out the objectives, the scope, the beneficiaries, the agents who carry out the activities of the system and the transformation processes by which the inputs are transformed into defined outputs and the environmental constraints.

In stage 4, conceptual models relevant to root definitions are built up into human activities that the system should undertake in order to be the system so defined. In stage 5, the conceptual models which are thought relevant to the problem situation are compared with what exists in the real world as seen from stages 1 and 2. This is done best in cooperation with the real owners of the problem with the object of generating a debate about possible changes which might be introduced in order to improve the problem conditions.

In stage 6, based on the debate carried out, feasible and desirable changes in the system are worked out and solutions recommended. The final stage 7 consists of implementation of the action agreed upon.

In practice depending upon the complexity of the problem situation it may fall anywhere in the range between the two extremes, enabling structured formulation of the problem situation partially and integrating this part into the overall system to be tackled by the soft problem methodology. The identification of this structured part in the problem situation, and the root definition arrived at stage 3 of the soft system methodology with all the world views, concerns and environmental constraints, will ultimately project the goals in concrete terms.

CONCLUSIONS

Conceptual models, depicting the farming activities of the household as a system identify all the components/sub-systems and their interdependencies with the help of flow charts and feed back loops, and the effect of environmental factors on the system, enable us to comprehend the complexity of the problem situations and help to locate the components for intervention with the hope of improving the system behaviour. The role of quantitative models in providing decision support at the different stages of Farming Systems Research is crucial. The enterprise selection, technology adoption and execution of the various developmental activities need to be undertaken after proper evaluation of the available alternatives, and choosing the ones which can exploit the potential to the optimum under the resource constraints keeping in view the objectives and the preferences of the household. Soft systems methodology is another way of tackling unstructured problem situations.

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efficient use of limited land and capital is made through improved farming systems and practices.

The problems of unemployment and under-employment lead to low income and investment on small farms. The problems of (under)employment vary between seasons (peak labour requirement), gender groups and between agro-economic zones. Vijayalakshmi *et al.* (1993) hypothesize that in the villages around Karnal the labour is relatively scarce compared with systems in Gujarat and around Bangalore (Karnataka). It is essential to develop, introduce and test technically feasible, economically viable, socially acceptable and sustainable farming systems and relevant technologies for small holders to increase farm income and productivity of labour (Amir and Knipscheer, 1989). This paper discusses the economics of dairy, crop and mixed farming systems on small farms in rural areas, comparing these with the results of dairy demonstration units (DDU) in on-station research trials at NDRI, Karnal.

MATERIALS AND METHODS

Data for the year 1989-1990, pertaining to cross-bred cattle and buffalo farming systems were collected from the official records of DDUs of Krishi Vigyan Kendra (KVK) at the National Dairy Research Institute, Karnal. These units test the combination of different proven techniques in farming systems and serve as a demonstration for small farmers (NDRI, 1978). Two systems are compared : one with three cross-bred cows and one with three buffaloes, using one acre for each unit. The units are managed by one permanent labourer each. The variable cost of producing fodder, excluding human labour, on one acre has been taken as the green fodder input in milk production in dairy units. The capital investment and various fixed costs of DDUs have been updated, keeping in view the prevailing prices of various assets. Data for crop production were compared using on-farm crop research trials conducted on farms in the Operational Research Project (ORP) villages adopted by the Institute (Patel *et al.*, 1988). Data on mixed farming systems for the year 1989-1990 were collected from 40 randomly selected small farms in ORP villages. These sampled farms were not participating in on-farm trials. They had an average operational holding of 1.2 ha; ranging from 0.1-2 ha. The prices prevailing in rural areas of various inputs and outputs and wage rates for a permanent labour along with standard farm management concepts have been used to work out various costs and returns. Family labour income has been worked out by adding imputed value of family labour used to net income.

RESULTS AND DISCUSSION

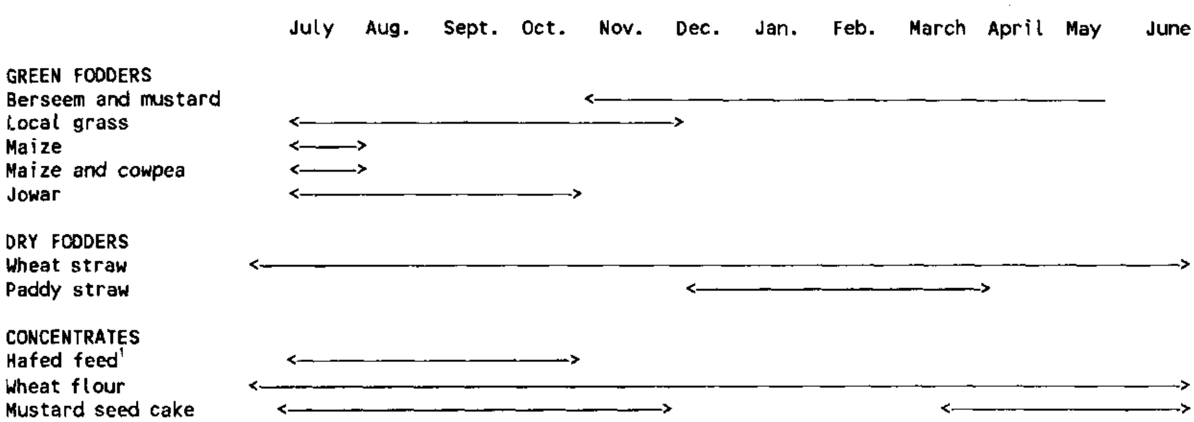
The ORP on integrated milk and crop production, launched by the NDRI in 1975, has followed an approach which is very similar to what is now termed as Farming Systems Research/Extension or

Development (Simmonds, 1986; Patel *et al.*, 1993). Efforts have been made in the project to evaluate research and development results in terms of whole farming systems as perceived by Shaner *et al.* (1982). The economic impact of various technological interventions in dairy and crop farming on productivity, employment and income has been assessed, on sampled farms in the project area.

Dairy Farming Systems of the green revolution belt

The Karnal district of Haryana is part of the green revolution belt that extends from Punjab via Haryana into Western Uttar Pradesh. Most buffaloes and cows in this district are of non-descript type. Buffaloes are reared by farmers for milk production and cows produce cross-breds for sale even to distant states as Bihar, Orissa, Gujarat and Maharastra, as well as for milk production, partly depending on the socio- economic category that keeps the animals. Cows also produce bullocks for traction and transport. By and large, a subsistence level of dairy system is practised by small holders. Small farmers keep 2-3 milch animals of low genetic production potential which are maintained mainly on crop residues. Paddy in kharif (rainy) season and wheat in rabi (winter) season are the most important cereal crops grown in the area which occupy about 71 and 75% of total cropped area on small farms in the respective seasons whose by-products, i.e. straws are fed to the animals. Wheat straw is a more common dry fodder and only in scarcity conditions paddy straw is fed as well. After cereal crops, fodder crops such as maize, sorghum, berseem, oats, etc. occupy the second position in the cropping pattern. These green fodders are chaffed and mixed with dry fodder for feeding to the animals. In addition, small quantities of concentrates in the form of wheat grain or home made mixture of grains and cakes are also fed (Some farmers also buy complete concentrate feed available in the market). An approximate feeding calendar for buffaloes is presented in Figure 1.

Figure 1 Feeding calender for buffaloes on small farms.



[1] a brand name for a commercial concentrate mixture.

Cross-breeding of local cattle with pure Holstein Friesian and upgrading of buffaloes with pure Murrah is done through artificial insemination to improve the genetic potential. With the introduction of cross-bred cows and new forage crops in the dairy sub-system, local cows are being replaced and new farming systems have emerged because farmers in the ORP area have found cross-bred cows more profitable than local cows. In view of the large number of alternatives available to the small farm households, farmers have to make complex decisions about the selection of profitable enterprises and allocation of scarce resources in highly variable recommendation domains (Hildebrand, 1981; Sharma and Singh, 1986).

Economic Analysis of Dairy Farming Systems

Although it is difficult to model complex farming systems due to large variations in feeding and management practices, economic analyses such as a simplified budgeting technique has been used for comparing cross-bred and buffalo farming sub-systems in order to provide information to the policy makers, planners, scientists, extension personnel and the farmers. Economic analysis of cross-bred and buffalo farming sub-systems was carried out and results are presented in Table 1.

Total capital investment of INR 35000 and INR 3800 was made on three cross-bred cow and three buffalo demonstration units, respectively, with each unit controlling one acre of irrigated land where intensive fodder crop rotations are followed to provide sufficient green fodder to the three animals. Further, the calves are weaned away on these units though this is not common practice on rural farms. If a three plot system of fodder production is followed, it can meet the green fodder and crude protein requirements of four adult milch animals in almost all the months of the year except in November (Singh, 1987).

The total variable cost of production was higher for cross-bred cows than for buffaloes due to higher cost of green fodder inputs, concentrates and veterinary aid (Table 1). Feed was the major component of cost of milk production accounting for about 43 and 41 per cent of the gross cost for cross-bred cows and buffaloes respectively while total variable cost of production was accounting for about 66% and 62% of the gross cost respectively.

However, various researchers in the country have observed different proportions of feed cost in the gross cost of milk production for different types of milch animals (Bagi, 1985; Kumar, 1986; Kumar *et al.* , 1984; Patel *et al.*, 1981; Patel *et al.*, 1983; Sharma and Singh, 1985; Singh *et al.*, 1979; Singh, 1991). Feed cost ranged from 43% of gross cost for non-descript local cows in Jammu and Kashmir state (Singh, 1991) to 62% in Uttar Pradesh (Kumar, 1986). In case of buffaloes, feed cost accounted for about 39% in Maharashtra (Bagi, 1985) and 66% in

Andhra Pradesh (Patel *et al.*, 1981). However, for cross-bred cows, it varied between about 44% in Jammu and Kashmir (Singh, 1991) and 73% in Uttar Pradesh (Kumar, 1986). This large variation in the share of feed cost in gross cost could be attributed to the difference in cropping and feeding systems, prices of feed inputs and breeds of animals etc.

Table 1 Breakdown of cost and income of milch animals on specialized dairy demonstration farms on one acre each.

Items	3 cross-bred cow unit		3 buffalo unit	
	INR/yr	% of total	INR/yr	% of total
VARIABLE COST				
Green fodder input	3272	11	2951	10
Dry fodder	181	1	302	1
Concentrates	9013	31	8457	30
Veterinary, water electricity etc.	1847	6	724	3
Human labour	5000	17	5000	18
Total variable cost	19313	66	17434	62
FIXED COST				
Land rent	2000	7	2000	7
Depreciation and interest on fixed capital	7675	26	9040	32
Total fixed cost	9675	33	11040	39
Gross cost	28988	100	28474	100
RETURNS				
Milk production (l/yr/herd)	10393		7565	
Gross return	33259		31773	
Gross margin from milk only	13946[1]		14339[2]	
Net return from the unit	4271		3299	
Net return per cow/buffalo	1424		1100	
Family labour income from the unit	9271		8299	
Family labour income per cow/buffalo	3090		2766	

[1] 3.2 INR/liter; [2] 4.2 INR/liter

The net return per cross-bred cow per annum was approx INR 1424 as against INR 1100 from a buffalo. The relatively higher net return from cross-bred cows could be attributed to lower fixed cost in spite of a higher feed bill. Family labour income per milch animal per annum was INR 3090 and INR 2766 from cross-bred farming and buffalo farming sub-system respectively. This suggests that a cross-bred cattle farm could be superior to buffalo farming system, with larger scope to increase income and labour opportunity for the unemployed and under-employed small farmers.

Economics of milk production from different species of milch animals, viz. cross-bred cow, buffalo and local cow reared by small farmers in the adopted ORP villages show a different result in terms of inputs and output based on the random sample of 40 farmers (see Table 2). Total variable cost of production for a cross-bred cow and a buffalo on small farms sampled in the ORP area was about half that on Dairy Demonstration Units. In absolute terms, cross-bred cows recorded the highest total variable cost of production (INR 3382) followed by buffaloes (INR 3123) and local cows (INR 2316) accounting for 66, 65 and 69% of the gross production cost respectively. The higher cost of milk production for cross-bred cows could be ascribed to higher cost incurred on green fodder input, concentrates and human labour. The net returns from a cross-bred cow, buffalo and local cow were about INR 696, INR 425 and minus INR 451 respectively based on revenue from milk production only. This again indicated that the cross-bred cow was more profitable than the buffalo on small farms as well. The break-even analysis of buffalo keeping showed that milk production of 1307 l/cow/yr covered only gross cost of production (Singh, 1988) due to low milk price received by the farmers. The local cow could not generate sufficient gross income to cover the gross cost of production. Further, family labour income generated by a cross-bred cow was about 3.7 times higher than that of a local cow on small farms. However, there was a big gap between the dairy income obtained on Dairy Demonstration Units and small farms. This gap can be due to various reasons which need to be identified.

Table 2 Cost and income breakdown for milch animals on small farms in ORP

Items	Cross-bred cow		Buffalo		Local cow	
	INR/animal/yr	% of total	INR/animal/yr	% of total	INR/animal/yr	% of total
VARIABLE COST						
Green fodder input	673	13	620	13	478	14
Dry fodder	679	13	836	17	635	19
Concentrates	617	12	526	11	175	5
Veterinary and Misc.	135	3	117	3	44	1
Human labour	1278	25	1024	21	984	30
Total variable costs	3382	66	3123	65	2316	69
FIXED COST						
Land rent	380	7	350	7	270	8
Depreciation and interest on fixed capital	1420	27	1365	28	761	23
Total fixed cost	1800	34	1715	35	1031	31
Gross cost	5182	100	4838	100	3347	100
RETURNS						
Milk production (l)	1837		1253		905	
Gross return from dairying	5878[1]		5263[2]		2896[1]	
Gross margin	2496		2140		580	
Net return	696		425		(-) 451	
Family labour income	1974		1449		533	

[1] 3.2 INR per liter; [2] 4.2 INR per liter

It has been reported that inclusion of dairy enterprise in crop farm plans increased farm income and employment on small farms as reported by Devadoss *et al.* (1985) and Sirohi *et al.* (1980). This may be true for many of the mixed farming systems in India, though dairy farming may not be profitable in the situations where favourable price ratios of milk and feed do not exist. Further rationalization of the use of resources in crop, dairy and poultry farming may lead to increased labour absorption in mixed farming systems on small farms where disguised unemployment exists. Thus, introduction of dairy enterprise with cross-bred cows in mixed farming systems could increase income and employment potential on small farms (Singh *et al.*, 1981).

Economics of Crop Farming System

Based on the random sample of 40 farms in the ORP area, nearly 67% of the total cropped area during the year was occupied by paddy and wheat crops. About 20% of the cropped area was allocated to fodder production in the ORP area as against only about 4% in the country as a whole. This higher area under fodder crops is due to good irrigation facility and concerted efforts made for the development of fodder resources in the cattle development program of the project, particularly the introduction of cross-bred cows.

Table 3 Economics of paddy and wheat production in on-farm research trials and small farms (INR per hectare).

Items	On-farm research in ORP areas				Small farms in ORP areas			
	Paddy		Wheat		Paddy		Wheat	
	INR/ha	% of total	INR/ha	% of total	INR/ha	% of total	INR/ha	% of total
VARIABLE COST								
Seed	79	1	375	5	73	1	299	4
Fertilizers	1223	14	1086	14	1082	13	984	13
Manure	-	-	-	-	39	0	-	-
Human labour	1911	22	980	12	2126	24	995	13
Bullock labour	165	2	182	2	301	3	261	3
Tractor charges	900	10	888	11	658	8	878	12
Tubewell charges	414	5	164	2	453	5	137	2
Other cash expenses	177	2	405	5	126	1	100	1
Interest on cash expenses	87	1	90	1	50	1	65	1
Total variable cost	4956	56	4170	52	4908	56	3719	49
TOTAL FIXED COST*	3876	44	3876	48	3876	44	3876	51
Gross cost	8832	100	8046	100	8784	100	7595	100
Yield (kg/ha)	5900		4500		5000		3200	
Gross income**	13532		11587		12705		8519	
Net income	4700		3541		3921		924	

* This includes depreciation and interest on the value of fixed assets, such as farm shed, machinery, equipments etc. ** includes income from straws as per opportunity cost.

To fill the existing yield gap in crop productivity, on-farm crop research trials of various cereal, fodder, pulses and cash crops are conducted on farms in the ORP villages. To examine the profitability, the cost/revenue breakdown of most important cereal crops, viz., paddy and wheat production on small farms in the ORP area are compared to the on-farm research trials conducted in ORP. Table 3 shows that the total variable cost in on-farm research trials was higher than that of sampled small farms mainly due to higher fertilizer and tractor use which has led to higher grain yield and higher income. The average yield in on-farm research trials (OFR) was about 5900 kg/ha as against 5000 kg/ha on small farms. The net income obtained from paddy in OFR trials was approx INR 4700/ha as compared to INR 3921/ha on small farms. Similarly, in case of wheat, better quality seed and higher fertilizer dose gave higher yield and net income in on-farm research trials than on small farms. It may be concluded that productivity and net income of crops in crop farming sub-system on small farms can be increased through the rational use of improved inputs which can be demonstrated by conducting on-farm as opposed to pilot units crop research trials.

Economics of Mixed Farming Systems

Dairy farming in the Indian context is mostly an integral part of mixed farming, with a wide variety of crop and animal interactions. To synthesize data on 'improved practices' into a synthetic farm model, we created the "On-farm Mixed Farming System Model". Table 4 summarizes costs and returns for 3 separate farm activities, each of one acre : the cross-bred cow and buffalo units from the Dairy Demonstration Units and the crop costs and returns from the on-farm crop trials conducted with farmers in the ORP villages. The summary represents the potential of a mixed farming system on 3 acres but simplifies for crop inputs (straw, stover, bran, etc.) into the livestock system or vice-versa by calculating their opportunity costs.

This mixed farming system is then compared to two groups of farms identified in the random survey of 40 farms carried out in ORP villages. These sample farms average 3 acres each and are thus comparable in size to the model mixed farming system. The difference between small farm system I and II represents the fact that two different combinations of dairy animals were kept on 0.5 acre devoted to fodder crops and the remaining 2.5 acres have been allocated to paddy-wheat rotation. In case of dairy system I, one buffalo and one local cow along with one buffalo heifer and two young stock were maintained while in the case of dairy sub-system II, one buffalo and one cross-bred cow alongwith one cross-bred heifer and two young stock were raised.

Net returns from the mixed farming system in the demonstration unit was INR 10866 as compared to INR 4124 and INR 5352 from mixed farming system on small farm in situations I and II, respectively (see Table 4). Similarly, human labour absorption and family labour income in the mixed farming system was considerably higher than that of mixed farming systems I and II on the survey farms. Integration of three farming sub-systems on the demonstration farm can further increase the income through rational use of resources and interrelations between the sub-systems. Introduction of cross-bred cows along with improved package of practices in dairy and crop farming systems can substantially increase income and employment on small holdings as the existing farming systems are relatively less efficient.

Net income from dairy farming sub-system with one buffalo and one local cow was negative due to low productivity of the animals, i.e. incomes and human labour absorption in the existing mixed farming systems on small farms is low due to low animal and crop productivity. This needs to be improved through introduction of new technologies in dairy and crop farming sub-systems.

Table 4 Economics of Dairy, Crop and Mixed Farming Systems on Demonstrations/On-farm Research Trials and Small Farms.

Items	Demonstration farm results				ORP survey					
					Small Farms - I			Small Farms -II		
	3 cross-bred cows on one acre	3 buffaloes on one acre	Crop farming on one acre	Mixed farming on three acres	Dairying (buff + local cow on 0.5 acre	Crop farming on 2.5 acres	Total of dairy + crop	Dairying (buff.+ crossbr cow on 0.5 acre	Crop farming on 2.5 acres	Total of dairy + crop
Variable cost	19313	17434	3651	40398	8153	8626	16780	9250	8626	17876
Fixed cost	9675	11040	3101	23816	3126	7752	10878	3785	7752	11537
Gross cost	28988	28474	6752	64214	11279	16378	27658	13035	16378	29413
Gross return	33259	31773	10048	75080	10558	21224	31782	13541	21224	34765
Gross margin	13946	14339	6397	34682	2405	12598	15002	4291	12598	16889
Net return	4272[2]	3299	3296	10866	-721[2]	4846	4124	506[2]	4846	5352
Family labour income	9271	8299	4453	22023	1937	6291	8229	3523	6291	9814
Human labour employment (days)	365	365	84	814	194	146	340	220	146	366

[1] total from cross-bred cattle and buffaloes and crops;
[2] too high because young stock is not included

CONCLUSIONS

Based on the above results, it may be concluded that for the area under study, mixed farming with cross-bred cow in the dairy component generates higher income and employment than the local cows on small farms. Further, introduction of specialised dairy units of cross-bred cows/buffaloes along with high yielding varieties of crops and new technlogy of crop production on small farms has potential for higher income and employment. Therefore, there is a need to develop and introduce improved farming systems to increase income and employment of the small holders through the adoption of Farming Systems Research approach.

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BIOECONOMIC MODELING IN FARMING SYSTEMS RESEARCH: A CASE STUDY OF DAIRY IN THREE STATES OF INDIA

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SUMMARY

Optimum production plans for mixed farming systems with mixed crop and dairy enterprise as source of income were developed by using linear programming. The models included physical, financial and biological aspect of the system by analysing average and generalised small farm situations from three different Indian states. One of the cases was studied with a static model for seven technology combinations. All three cases were studied with a multiperiod program on only one technology combination. The possibility to reduce the yield gap between potential and actual performance of cross-bred cows by enhancing the nutritive quality of straw by urea/ammonia treatment was studied. It is clear that the technique of feeding urea treated straw can be complementary to current cross-breeding programs in India only in certain farming systems. The modeling exercise showed a) the importance of the feeding sub-system in the overall system and the effect of the seasonal availability of straw and b) the major limiting factor with the assumptions in the static model seem to be "feed" in the dry farming areas of Baroda, "capital" in the Bangalore system and "labour" in the irrigated area of Karnal. The dynamic model showed that a) initially capital is limiting in the Bangalore case, but that feed becomes limiting over time if no animals are sold, b) in general, availability of working capital increases the resource utilization in all three situations, c) strategic decisions such as investment on animals can be better understood if the optimum plan covers more than one year and/or seasons, d) the limitations of modeling exercises stem from lack of data regarding rainfall distribution, dung management for fuel, crops and marketing, labour utilization, feeding system and farmers' management practices for output and input utilization.

INTRODUCTION

Many agricultural production systems in developing countries are based on mixed farming with a tradition of crop-livestock integration. The density, concentration and combination of various categories of livestock are related to natural factors

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(climate, soil condition), and man-made factors (irrigation, type of farming, cropping pattern and size of holding).

The allocation of resources over time depends on the efficiency of each farm enterprise and overall system performance, based on (biological) interactions of soil, crop and animal components in mixed farming system. Efficiency and system performance depend in turn on level of sophistication and types of production and marketing technologies employed, and in particular on the management skills and abilities of the farmer. That is, the rate at which the resources of the farm are utilized, conserved, revised and reinvigorated depends on biological and ecological as well as on peripheral economic and social constraints.

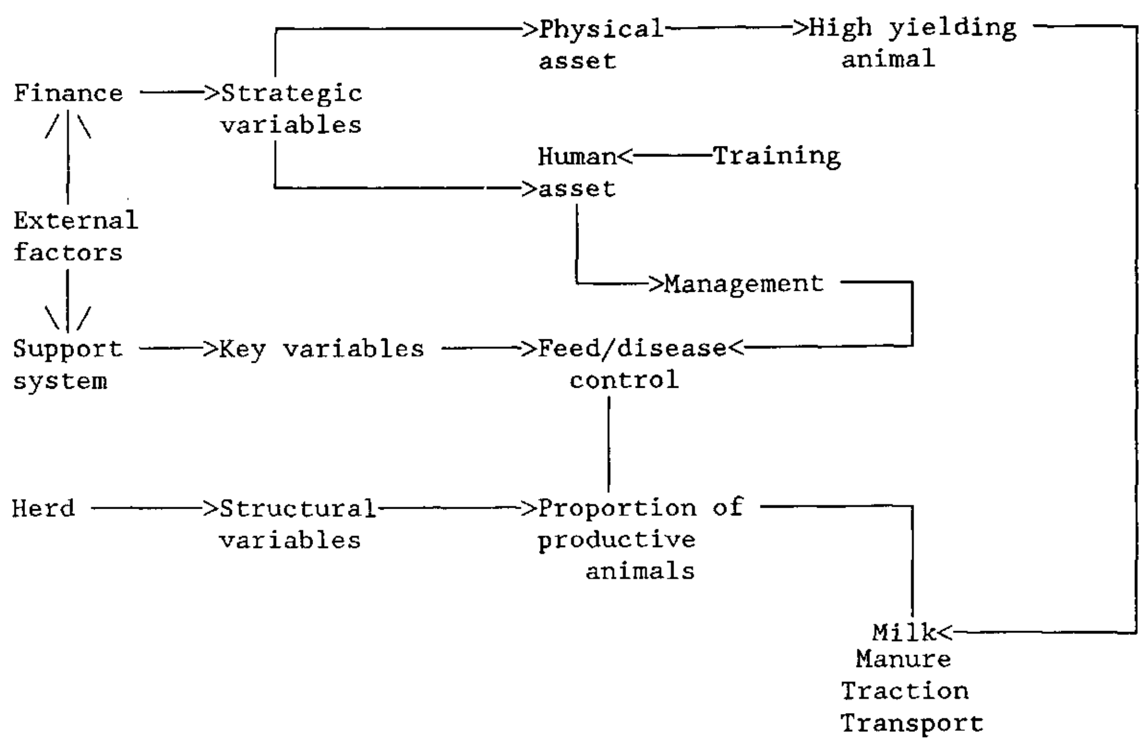
Resource allocation decisions made at one point, affect farm operations for months or even years to come. This is arguably more critical in livestock enterprises. Factors such as the mobility of animals and their long life cycle, non-divisibility and size of units, multiplicity of outputs etc., make the decision making complex (Baker *et al.*, 1988). The animal sub-system in India is undergoing radical changes, primarily by a shift to commercial dairying and decreasing fodder resources (Jodha, 1986 ; Vaidyanathan, 1981). The production efficiency in terms of realization of superior genetic potential of (cross-bred) cows depends on production and management factors and interaction exists between biological characteristics of a cow and optimum management (Van Arendonk, 1988). The social organization of agriculture in developing countries is based on a large number of small family-operated farm units (FAO, 1988). The linkages within the sub-system (Figure 1) shows that the human asset of the farm needs to be supplemented periodically by improved management skills/knowledge infusions for both farm men and women. The cumulative and long term nature of human resource development process is a significant and strategic variable in the system (Gill, 1990).

The majority of farm families in India (with an average of less than two hectares) are often subjected to uncertainties of the monsoon. Such farm families have always sought to wrest a livelihood in remarkably diverse ways, e.g. small farms diversify their enterprise mix, existing resources are put into multiple use and multiple use of a crop or animal is sought. Isolated attempts by each discipline to transfer improved technology to (small) farms are undertaken, but they invariably only touch the fringe of the problem (Haverkort *et al.*, 1988). A superior approach would employ holistic methods of transferring technology incorporating all biological (soil, crop, animal), engineering, and soci-economic aspects, including new or upgraded management skills. This implies the need for a systems approach.

The concept of systems thinking became again popular among agriculturists about two decades ago, and is undertaken on different levels (Dent, 1975; Patel *et al.*, 1993; Fresco and

Westphal, 1988; Conway and Barbier, 1990):
- bio-chemical and physical systems,
- plant and animal systems,
- farm business systems,
- national and international systems.

Figure 1 Farm Production Linkages in a Dairy Sub-system.



The application of systems concept at farm level by model building is difficult when biological data are assessed according to socio-commercial criteria (Dent, 1975). Moreover, dynamics are extremely important in any farming system with biological processes, different resource requirement over seasons, cash flows over years for long term investments and the time lag between input and output. Decision making in agriculture realistically operates in a multi-period environment (Stonehouse, 1981).

Recently, increased focus is put on blending crop-livestock technology, to ensure that farms achieve optimum exploitation of crop biomass for animal production and effective utilization of animal traction and manurial value for crop production. Multi-level farm activities are not yet evaluated sufficiently in an integrated and comprehensive manner while addressing policy

issues involving the provision of physical, financial and social stimulants to the farming community, e.g.:
- new grain varieties are introduced with little attention to straw quantity and quality for animal feeding,
- programs of dairy cattle cross-breeding does not sufficiently consider the availability of feed resources.

The farming system approach is a research imperative to provide appropriate decision support: in strategic, structural or in key/critical variables of production-modeling of whole farm enterprises including linkages (Charlton, 1975). Models need to be built on sound data (Swaminathan, 1981) and theoretical underpinning and include:
- zone-wise typology of soil, water holding capacity of soil, humus content and extent of erosion due to wind, water etc. (Jain and Dhaka, 1993);
- efficient ways to replenish soil nutrients with livestock excreta;
- the breed and the type of animal suited to be raised economically on the forage, crop residues and other by-products that are locally available;
- post harvest technology to utilize other food/fibre available for the use of dairy animals (Sampath, 1983).

OBJECTIVES OF THIS STUDY

Development efforts aimed at integration of crop and dairy enterprises have resulted in general improvements for small farmers, whose potential income gains were often larger than for large farms (Banerjee, 1987). However, the reverse could be true in other areas where adequate infrastructure does not exist. Simultaneous and integrated introduction of technology for crop production by improved seeds, of milk production by improved breeds, sustained by improving feed resources and feeding systems can accelerate the growth of farming communities. This paper describes the (simultaneous) introduction of three technologies:
- new seeds (high-yielding variety),
- use of dairy breeds (cross-breeding),
- improved availability of feed (treated straw).

The introduction of these technologies was simulated for generalized and hypothetical small farm situations of three farming systems in the districts of Bangalore (Karnataka State), Karnal (Haryana state) and Baroda (Gujarat State).

The cases were modelled by using multi-period linear programming (Stonehouse, 1981) to estimate the optimal farm plans. The main objectives of these models were:
- to design optimum farm plans at different levels of technology for the whole mixed farm situation, integrating physical, financial and biological resources of small farm situations,
- to study the stability of the system by adding a dimension of time and risk.

Many alternative empirical modeling techniques were considered for this study, including econometrics, simulation, and mathematical programming models. The last of these appeared to be the most desirable because:

- the problem setting to be analyzed reflects the small farmer's desire to find the most efficient method of allocating scarce resources, given multiple input opportunities, including alternative technologies, and given multiple output choices;
- the range analysis option available with mathematical programming techniques provides useful information about the stability of optimum solutions obtained;
- the duality theorem associated with mathematical programming techniques ensures the derivation of "shadow prices" (or marginal value products) attached to those farmer's resources that are in scarce supply, thus revealing where the most important production or marketing bottlenecks are in any farming system.

In particular, multi-period (as opposed to static) linear programming models were selected in order to embody the all-important time dimension in small farm business studies. The time dimension was incorporated in two important respects. First, intra-year structures allowed for seasonal crop production analysis so important in the multi-cropping setting in India, and also permitted analysis of cash flow and short-term credit needs. Second, inter-year structures allowed for biological production time lags associated with bovine reproduction and herd replacement to be analyzed. Furthermore, the indivisible nature of dairy herd units was felt to be critical, especially for small farms in India where cow numbers may total only from two to six. In order to obtain only integer activity level result for all livestock real variables, these variables were declared integer types in the models. Thus, the modeling technique used was the multi-period, mixed integer programming approach.

THE MODEL: ASSUMPTIONS AND STRUCTURE

Agro-climatological details of the districts and resource levels of the small farms are given in Table 1. Data for Bangalore were updated with 1988-1989 prices along with the technical coefficient details of a past study (Vijayalakshmi, 1985). The information on the Baroda and Karnal situation is simplified and taken from unpublished data of the other authors.

The optimum plans for seven combinations of technology adoption were studied with a static plan. The stability of the final model was further tested with a dynamic model. Both the static and dynamic models were based on the work of Vijayalakshmi *et al.* (1990). They consider an optimum plan over four years, explicitly allowing changes in herd structure, and using calf and heifer mortality of 20%, delayed calving for 50% of milch cows and a 10% inflationary trend for input and output prices. The dynamic model

Table 1 Description of the study area and farm characteristics.

Particulars	Unit	District of		
		Bangalore (Karnataka)	Baroda (Gujarat)	Karnal (Haryana)
Agro-climatological information				
Av. Rainfall	mm	794	750	700-1200
Temperature	°C	12 to 30	10 - 45	2 - 40
Soil type		Red loamy	Black with heavy clay	Loamy
Major food crop		Fingermillet	Sorghum	Wheat and Paddy
Average Small Farm Situation				
Operational land holding	ha	2	2	1.2
Irrigated area	%	20	0	100
Family size	persons	6.28	6.9	6.39
Family labour	persons	3.68	3	2.33
Milch animal/household	animals	3.59	1	2.11
Herd size/household	animals	5.59	6.1	5

connects farm investment decisions for buying of cows on borrowed money over four years with repayment of loan and interest rate. A female calf born in the first year was considered to be a growing animal up to the third year, after which it starts to produce milk. A female calf born in the second year would start lactating in the fifth year if feed would be sufficient.

RESULTS AND DISCUSSIONS

In order to test the structure of the empirical models and validate them in a logical and systematic fashion, model-building proceeded in stages. First, a static (one year) linear programming model was developed. This was extended to a multi-period linear programming, and finally the dairy livestock activities were put in integer from (i.e. fractions of livestock numbers were not allowed).

The static model: Case I - Bangalore

The different levels of techology are shown in the top part of Table 2 for the static LP model.
Resource utilization and income for each plan is shown in Table 2. With INR 10000 for working capital, different levels of

technology introduction gave different combinations of crop and dairy for the total enterprise. In general, unirrigated land was utilized for fingermillet, sorghum and fodder trees, and irrigated land was utilized for paddy, maize and groundnut. The number of dairy animals in each plan varies between 2 to 3 (Vijayalakshimi *et al.*, 1990). The general conclusion from the optimum plans are that:

- an increased level of technology on crop and dairy can increase farm income;
- the requirement for feed purchases are affected by seasonal fluctuations in farm produced by-products;
- treatment of straw can be cost effective, irrespective of level of technology. This can be explained because the model assumes reasonable level of milk production, marketing possibilities and cheap availability of home-grown straw. Therefore, in this case the conditions for successful straw treatment are fulfilled as described by Schiere *et al.* (1988) and Kumar *et al.* (1993). Furthermore, only one technology is considered, and no inference can be drawn over the usefulness of other technologies.

It should be noted that a higher technology adoption in crop/dairy enterprise should require more managerial skill for integration of crop and dairy production. This is not, however, reflected in the farm plan.

The dynamic model for Bangalore, Baroda and Karnal cases

Case 1 - Bangalore

The feasibility of paddy straw treatment over four years under the conditions of plan 7 in Table 2 was further tested in a dynamic model (Table 3). The results of the plan with treated straw shows an impact in the optimal farm plan only in the fourth year when one female calf of year one started to produce milk. However, the plan was infeasible if all the calves in year two start to produce milk in the fifth year because of feed shortages. Calf management will have to be modified to adjust for this. With the starting capital in year one as INR 30000 and 20000 in the subsequent years the plan allows in the first year 3.9 cross-bred cows producing a total of 7100 kg of milk. In the second year, due to the presence of some animals with prolonged dry days, the milk production decreased, to again increase in year 3 and 4 by the advancement of lactation number of milk cows and entry of a heifer as milk producer in the fourth year. The crop production shows a stable income with 100 percent cropping intensity except in year one where the annual crop of fodder trees occupied only 0.5 acre. The entire straw supply was fully utilized in 4th year where the number of animals exceeded six. Up to the fourth year the higher straw requirement was met by increasing the area under fingermillet. However, dry fodder availability becomes limiting in the fifth year, where the number of animals was further increased and if no disposal (sale) of animals was allowed (Vijayalakshmi *et al.*, 1990). Therefore the model should be expanded by providing marketing options for animals.

Table 2 Resource utilization and income generated by different technology combinations, according to the static model for the Bangalore case.

Details		Plan1	Plan2	Plan3	Plan4	Plan5	Plan6	Plan7
Level of Technology (%)								
Seed		0	50	50	50	50	100	100
Breed		0	0	0	100	100	100	100
Feed		0	0	100	0	100	0	100
Land								
Cropping intensity(%) (*)		46.8	87.1	92.2	94.6	85.5	85.2	85.2
Capital								
Utilized	INR	7252	8427	16234	14428	15155	17151	16982
For feed alone	INR	4643	4303	4199	10624	10829	13898	9794
Income from								
Crop	INR	2499	9217	10733	9922	10007	11735	11977
Dairy	INR	4096	4056	4056	16764	18324	16764	18520
Others (**)	INR	2400	-	-	-	-	-	-
Total	INR	8995	13273	14789	26686	28331	28499	30497

(*) cropping intensity = net cropped area from all crops / level area devoted to crops; (**) others = non farm activities, i.e. wage for outside labour.

Table 3 Credit and cash flow statement for four years-with treated straw**, based on dynamic linear programming model results for Bangalore Case Study.

Details	Year 1	Year 2	Year 3	Year 4	Total
Loan outstanding	9672	8221	5803	2901	
Interest paid	1354	1151	812	406	3723
Repayment of loan	1451	2418	2901	2901	9672
Cash outflow:					
Crop	6855	7555	7654	7784	29848
Dairy	20179	17435	15495	13705	66814
Total *	30950	28559	26862	24796	111167
Cash inflow:					
Crop	15743	20507	20507	20507	77264
Dairy	25632	25422	25181	31625	107860
Total	41375	45929	45688	52132	185115
Cash balance ***	10410	17370	18826	27336	73948

* includes repayment of loans both for capital investment as well as for working capital (short term purposes);
** data for use of untreated straw are available with the principal author;
*** excluding cost of family labour, since that is not limiting (Vijayalaksmi, 1985).

The credit and cash flow over four years based on the linear programming model for Bangalore is now described. With a starting capital of 30,000 in the first year and 20,000 in the each subsequent year the plan shows a cumulative income of INR 102400 for four years. Table 3 shows the details of the cash flow, which was calculated with dynamic model. There is an unequal cash balance of the farm over four years, but the cash balance becomes more positive at an increasing rate of the total loan amount for purchase of cows allowed as INR 12000, the plan utilized only INRR 9672. This is due to the roughage being sufficient to support an expanded herd size up to year 4. This is also indicated by the model results showing a gradual accumulation of concentrate feed over and above animal requirements (4 kg/day). The multi-period model with untreated straw had shown higher cash expenditure for purchase of feeds compared to the plan with treated straw, relating to the usefulness of straw treatment over years as discussed earlier.

Case 2 - Baroda

This case is an elaboration of the one discussed by Patil *et al.* (1993). More details of the farm situation in Baroda are needed to make the model more realistic. But the available information shows that with a free choice of cropping pattern, with the use of sorghum and cotton crop on rainfed area and INR 5000 as working capital, the model uses a cotton crop on the maximum area, and the sorghum crop was reduced to the requirement for home consumption. This indirectly limited the possibility to include a milch animal to less than one, due to limited availability of sorghum straw. When working capital availability was increased to INR 10000, still little more than one animal could be sustained, mainly using purchased feed. This type of feeding system is uncommon in the case study area, i.e. modifications were included such as the access to fodder from common grazing land and reduced area under cotton. With this modification, with INR 5000 as working capital, buffaloes entered the farm plan and milk sales contributed considerably to farm income. Cross-bred cows entered only at higher working capital availability. The dynamic model suggests use of a lower number of animals, and slower herd expansion, in the second year. Multi-purpose use of cattle and buffalo needs to be accounted for when building the model. The important points that emerge from this simplified and analysis with limited data are that:

- the feeding system of the area pre-supposes good pasture land for grazing at least 5 to 7 months in a year, which would require significant intervention by a wastelands rehabilitation or similar program;
- the multiple use of animals for "outputs" like dung, asset value etc. needs to be better quantified and incorporated in the model.

Case 3 - Karnal

The Karnal district has good irrigation facilities and gives optimum farm plans that differ from the Bangalore and Baroda cases. With INR 5000 as starting working capital and milk sales as an additional source of working capital, most income is derived from cropping. Even when the capital availability was increased to INR 10000 the optimum plan did not include enough animals to utilize all the straw and green fodder that was available in the plan. The reason can be that labour was the limiting factor during the kharif and rabi seasons where crop cultivation utilized maximum family labour. When the labour constraint was relaxed by hiring labour, the model gave less income. This indicates a combined limiting effect of capital and family labour for the small farm situation of the Karnal case, and also that hired labour is expensive compared with family labour (Singh *et al.*, 1993).

The Karnal case (with very limited data) shows the following points:
- labour should be allocated operation-wise to build a better model;
- more forage cropping can be done on summer fallow land, and vegetables could be a source of additional income for the family and feed for animals;
- feeding of chopped paddy straw and berseem should be considered as per the nutritive value of combined feed;
- labour availability could be a problem with these options but in the actual situation, chopping is indeed practiced (De Wit *et al.*, 1993).

CONCLUSIONS

The usefulness of technological innovations for livestock production cannot be seen in isolation from crop production, in cases where crops and livestock occur integrated on farms. Economic modeling can be useful to study the interrelations of the system, for *ex ante* analysis of effects of innovations and to determine constraints in the system. Especially livestock production is of a long term nature. It is affected by seasonal fluctuations in feed and labour supply as well as market prices. Moreover, a decision in one year is likely to affect the results of the system over years to come. Therefore not only static models, but also models with a time dimension are required for analysis of crop and livestock systems. With limited data available for three cases of distinct farming systems in India, it was tentatively shown that the three systems had also distinct constraints, i.e. capital and straw for Bangalore, concentrate feed for Baroda and labour for Karnal. The models and data used need to be refined, but the results show a need to design different development approaches as per the constraints in the prevailing farming system.

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FEEDING OF DAIRY ANIMALS BY FARMERS FROM HIGH AND LOW POTENTIAL AREAS

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SUMMARY

Feed availability and feeding practices vary between areas and seasons. This study analyses the resources, feeding practices and productivity of milk animals in high and low potential areas to work out nutritional status of animals. One year records of milk production and feeding of animals have been compiled and used to work out annual production of milk, as well as feed and fodder used. Nutritional status was calculated per season in both areas by considering average milk production and feed intake. The high potential area (HPA) farmers own more buffaloes and cross-bred cows compared to low producing area (LPA). In both areas large farmers own more buffaloes. The cropping intensity in the HPA is more than 250% as compared to 89% in LPA, mainly due to difference in availability of irrigation. The animals are mostly stallfed in HPA while they are grazing in LPA. Feeding of concentrates is more in LPA than in HPA. The average production from LPA is higher in local and cross-bred cows, in spite of non-availability of green fodder. Production averages were higher from animals of small farmers than of large farmers. Animals from HPA were fed excess crude protein (CP) and energy (TDN) to some extent, while CP was marginally deficient in LPA. Energy availability for local animals is adequate in both areas but deficit in the cross-bred cows of LPA. In local animals, income of LPA farmers is less than for HPA farmers. In the case of cross-bred animals, income from LPA farmers is higher than for HPA farmers. It seems that small farmers maintain animals better than large farmers and that income through dairy animals can substantially improve their economic status. Suitable methods should be developed to record more accurate data for intake by grazing animals.

INTRODUCTION

Livestock keeping is an important activity for many farmers in India, where mixed crop - livestock farming is traditionally practiced. The farmers keep a variety of livestock like cattle, buffalo, sheep, goat, and poultry for different purposes. In view of their contribution to the rural economy, livestock production is emerging as a major component of development programs, with dairy occupying the first position. During the 7th Five Year Plan, milk production reached 45 million tonnes and the Government has set a target of 60 million tonnes for the 8th

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Plan. This is proposed to be achieved by genetic improvement, along with better feeding and management. Feeding is recognised as one of the major constraints in livestock production and accounts for a large proportion of the cost of milk production (Singh *et al.*, 1993). Quantitative and qualitative shortage of feeds and fodder affects the performance of livestock, though both under- and overfeeding occurs and this affects economics of milk production negatively. The feed availability and feeding practices vary with area and season. Appropriate recommendations about improved feeding of dairy animals require detailed observations on feed resources, feeding practices and animal production. The data are to be analysed to understand the nutritional status of the animals and the expenses on feeding. The scientific community has realised these aspects and increasingly attempts to study the actual feeding pattern of (dairy) animals at different centres in the country. This paper summarises preliminary information on feeding systems as collected from the Operational Research Project area around Karnal (Haryana) by NDRI workers and around Juna Rampura Cattle Development Centre, in Baroda district (Gujarat) by BAIF workers. The paper supplements the information by Vijayalakshmi *et al.* (1993) in showing important differences between farming systems in India.

This paper highlights differences between farming systems observed in terms of feeding conditions, nutritional status and production costs for animals in these two contrasting situations. Based on this very preliminary work, suggestion are made to optimise the use of available resources, to correct shortages or to reduce excess in feeding systems.

MATERIAL AND METHODS

Area

The villages around Karnal represent a high potential area (HPA), with good soils and irrigation facilities. In contrast, the villages of the BAIF study area in Baroda district have no irrigation and poor soils with rain fed agriculture, i.e. they represent a typical low potential area (LPA).

The Karnal district is situated in the Eastern zone of Haryana State. The study around Karnal involves villages under the Operational Research Project, where the soils are predominantly very fertile loam or sandy loam with perennial irrigation facilities available from canal and wells (Ghosh, 1991). A cropping intensity of 213% is observed in these villages. Extremes of climate are experienced in Karnal area with average daily maximum temperatures ranging from 10 to 46°C and minimum temperatures from one to 33°C, with an average annual rainfall of 745 mm (NDRI, 1990).

The villages surveyed in the Baroda district have no irrigation facilities, the soils are poor, with low productivity and mostly single crops of rainfed cotton or sorghum are taken. The average rainfall is 750 mm/year and the temperature ranges from 12 to 46°C (Ghosh, 1991).

Survey and recording

In the NDRI study, observations were recorded on 63 farms from four villages, including 40 small and 23 large farmers. In the BAIF study, 190 farmers were studied from 20 villages, including 173 small farmers and 17 large farmers. Farm stratification is based on land holding. Farmers with less than 2 hectares land are classified as small farmer and those having more as large farmers. Such a classification may have to be reconsidered in the future as indicated by Jain and Dhaka (1993).

Baseline information included family size, literacy, herd size, herd composition, cropping pattern and milk yield (recorded at two week intervals of morning plus evening milking). Information on feed and fodder offered to the animals and their milk yield was recorded by weighing/measuring also at two week intervals. Information about grazing practices of animals, wherever it was practiced, included the type of grass prevalent in the grazing area, and the number of grazing hours during different seasons. The grass intake during grazing was calculated, using estimates from a study by the Indo-Swiss Project, Andra Pradesh (ISPA, unpublished). As a general observation, it can be said that the biggest problem in these studies is to obtain reliable estimates of feed intake, especially for grazing animals.

The records of milk production and feeding of animals has been compiled and analysed for one complete year, to know the annual milk production and feed and fodder used. The nutritional status was worked out seasonwise, by considering average milk production and feed - fodder intake. The nutrient requirements and intakes of the animals were based on average values from Sen *et al.* (1978). With regard to the body weights and fat percentage in milk, average values observed in the field have been taken only data for local and cross-bred cattle are considered in this discussion.

RESULTS AND DISCUSSIONS

Households

The general information on the families studied in the two projects shows that the average family size is larger in the Karnal area compared to Baroda area (Table 1). In both cases the family size is larger for the large farmers than the small farmers, for which no explanation can be offered at this instance. Not surprisingly however, a similar trend is seen with respect to livestock keeping which is higher for large than for small farmers. The former Maharaja of Baroda had done much work on education of the population. This is clear from the literacy which is higher in Baroda than in the Karnal area, but in both areas the literacy is higher among larger than among small farmers.

Table 1 General information of the sample households

Particulars	Baroda (low potential)		Karnal (high potential)	
	small farmer	larger farmer	small farmer	large farmer
No. of observations	173	17	40	23
Family size	6.9	7.6	7.8	9.7
Size of operational holding (ha)	1.7	9.2	1.2	4.9
Literacy status (%)	45	77	31	43
Herd size	5.4	12.5	6.6	10.0
Type of dairy animals (numbers)				
Local cow	0.5	0.7	0.4	0.5
Cross-bred cow	- *)	0.2	0.2	0.5
Buffalo	0.4	1.0	1.6	2.5

*) Less than 0.1.

Herd composition

The herd composition is different in the two areas. The Karnal farmers own more buffaloes and cross-bred cattle than the Baroda farmers. This is probably because the cross-breeding programs started only recently through the Juna Rampura centre of BAIF in the Baroda district. The herd composition reflects also traditional differences between the two areas. Though there is recent change, the Baroda region is not a traditional milk producing area, the change comes with improved organisation of milk marketing and availability of cattle breeding services. The difference in herd size could also reflect the productivity of the land. The larger farmers own more animals of all types and the number of buffaloes owned by large farmers in Karnal is higher than in any other category. The local cows in the Baroda region are of the Kankrej type while those in Karnal area are Haryana type. Buffaloes in the Baroda area are non-descript while those in Karnal are of the Murrah type. The cross-breds are usually with Jersey and Holstein inheritance in both areas. A recent reference on cattle breeds in India is provided by Gupta (1987).

Cropping pattern

As can be expected, there is considerable difference in cropping intensity and cropping pattern between the two areas (Table 2). Farmers from the Karnal area have 213 % cropping intensity compared to 89% intensity (in the rainy season only) in the

Baroda area, mainly due to lack of irrigation in Baroda. Farmers of the Karnal region use high yielding varieties of grain crops and they cultivate fodder crops on almost 19% of the land in a year. In contrast, the farmers of the Baroda area do not cultivate green fodder and thus crop residues and concentrate supplements are the only material available for feeding of the animals. The major crop residues in the Baroda region are from sorghum, paddy and pulse straws while in the Karnal region the residues are from paddy, maize, and wheat besides the green fodders like sorghum, maize, berseem and oats.

Table 2 Cropping pattern per season and year (share of crop in %)

Seasons/crops	Low potential area (Baroda)				High potential area (Karnal)			
	Small farmers		Large farmers		Small farmers		Large farmers	
	Per season	Per year	Per season	Per year	Per season	Per year	Per season	Per year
KHARIF								
Cereals and cash crops								
Cotton	33	33	47	47	48	22	58	28
Sorghum	21	21	25	25	-	-	-	-
Toria (pigeon pea)	15	15	9	9	-	-	-	-
Paddy (G)	19	19	8	8	-	-	-	-
Paddy (HYV)	-	-	-	-	23	10	26	13
Paddy (Basmati)	-	-	-	-	3	1	1	1
Fodders								
Maize	-	-	-	-	1	1	1	1
Sorghum	-	-	-	-	24	11	13	6
Vegetables	-	-	-	-	2	1	1	1
TOTAL	88	88	89	89	101	46	100	50
RABI								
Cereals and cash crops								
Wheat	1	1	-	-	75	34	86	41
Maize (g)	-	-	-	-	1	1	-	-
Barly	-	-	-	-	-	-	1	1
Fodders								
Berseem	-	-	-	-	21	10	11	5
Oats	-	-	-	-	-	-	1	1
Pulses								
Gram	-	-	-	-	1	1	1	1
Masri puls	-	-	-	-	-	-	-	-
Oil seed								
Toria (pigeon pea	-	-	-	-	-	-	1	1
Vegetables	-	-	-	-	3	1	1	1
TOTAL	1	1	-	-	101	47	102	51
SUMMER								
Cereal and cash crops								
Maize	-	-	-	-	13	1	11	1
Maize and Cowpea	-	-	-	-	52	5	50	2
Jowar	-	-	-	-	4	1	24	1
Pulses								
Urd (black gram)	-	-	-	-	4	1	4	1
Moong (green gram)	-	-	-	-	9	1	-	-
Vegetables	-	-	-	-	17	2	11	1
TOTAL	-	-	-	-	99	11	100	6

Feeding practices

One of the major differences observed between feeding practices of the two areas concerns the system of grazing versus stallfeeding. In the Karnal area the animals are generally stall fed, while in the Baroda area the animals are generally sent out for grazing except milk producing cross-bred cows. The time spent in grazing varies from season to season and ranges from 4 hours in summer to 6 hours in late kharif season. The animals from the Baroda region receive greens only in Kharif and early Rabi in the form of forest grass. The lactating cross-breds are offered some greens in the form of tree leaves, weeds and other browse.

To supplement the available fodder, farmers use concentrate that is either purchased or home made. The quantity of concentrate fed to dairy animals is relatively larger in the Baroda than in the Karnal region. The Baroda farmers probably know that they require to feed more concentrate because of the general lack of good quality green fodder (see Table 3).

Table 3 Input-output levels in lactating animals (kg feed fresh matter and liters/day).

Category of households/ seasons Milk	Low potential area (Baroda)				High potential area (Karnal)			
	Green fodder *	Dry fodder	Concentrates	Milk	Green fodder	Dry fodder	Concentrates	
LOCAL COWS								
Small farms								
Kharif	14.12	8.17	1.80	4.27	23.12	3.63	0.63	4.82
Rabi	5.00	8.43	1.53	3.13	25.25	4.83	0.21	4.12
Summer	-	9.27	2.37	5.42	25.00	4.19	0.06	4.15
Large farms								
Kharif	13.35	7.70	1.67	4.60	28.00	3.00	0.35	3.94
Rabi	6.80	8.26	1.50	2.86	26.25	4.25	0.56	3.91
Summer	-	8.75	1.97	4.50	19.29	4.86	0.86	3.80
CROSS-BRED COWS								
Small farms								
Kharif	11.67	5.05	2.07	7.30	31.88	3.63	1.18	7.91
Rabi	11.20	4.82	2.17	6.60	27.30	4.00	0.45	6.07
Summer	5.50	3.60	2.37	5.50	30.00	5.20	1.20	6.15
Large farms								
Kharif	-	-	-	-	26.40	2.40	1.08	7.11
Rabi	-	-	-	-	33.53	3.90	1.23	6.07
Summer	-	-	-	-	29.00	5.60	1.25	6.71

* includes intake of grasses through grazing in low potential area.

The amount of concentrate offered varies between seasons, with higher quantities generally offered during summer, i.e. the driest season. However, the data for small farmers from high potential area of Karnal show that less concentrate is offered to local cows on small farms in the summer than in Kharif and Rabi, an observation that is difficult to explain. However, the level of concentrate feeding is higher in summer than in other seasons for cross-bred cows.

Milk production

It is interesting to note that the average production from local cows in the low potential area of Baroda is higher in local as well as in cross-bred cows (Tables 3 and 4) than in the Karnal area, in spite of non-availability of green fodder. One explanation can be found in the sale of high yielding cows from the Karnal area to city farms and to other areas of the country, i.e. the cows are not milked on the farm, but in the city. The average production of cows kept by small farmers is better in all cases. This is probably due to better attention paid by small farmers to their animals, as also reported by others (BAIF survey, 1988).

Nutrient intake

A preliminary attempt is made to calculate the nutrient availability from feed offered to the animals in both the areas. The calculations indicate that the animals from the high potential area of Karnal are well fed and to some extent receive an excess of both CP and TDN. The data indicate marginal deficiency with respect to CP for local and cross-bred cows for animals from low potential area of Baroda region. The energy availability (TDN) seems to be relatively good for local animals in all seasons and for both the areas for cross-bred cows. However, an energy deficit is observed from the calculated figures for cross-breds in Baroda, while the area of Karnal shows surplus. The deficit in the low potential area increases in summer as well as the surplus for summer in high potential area. With regard to information on the nutrient availability one has to remember that the exact recording of feed intake is very difficult. This is more serious in the Baroda area where grazing prevails. Nevertheless, an attempt has been made to make an estimate of intake by taking into account the number of grazing hours and predominant grass species. There is a need for further work in this area considering the prevailing practice of grazing in most of the low potential areas in the country.

Income over feed cost

The income of the small and large farmers through dairying was calculated taking into account the feed cost and considering that small farmers may have different perceptions about aspects like interest, depreciation, importance of daily cash flow etc. (see Table 5). In case of local cows, the overall income of farmers from dairy in the low potential area is lower than in the high potential area, but the income of small farmers from dairy in the low potential area is lower than for larger farmers in the low

Table 4 Availability and requirement of nutrients for lactating animals on small farms.

Nutrients	Low potential area			High potential area		
	Kharif*	Rabi**	Summer	Kharif	Rabi	Summer
LOCAL COWS						
Average availability						
DM	12.40	9.98	10.56	8.98	10.59	8.83
CP	0.63	0.45	0.50	0.54	1.14	1.09
TDN	5.92	4.87	5.17	4.53	4.30	4.44
Requirement						
DM	8.75	8.75	8.75	7.50	7.50	7.50
CP	0.46	0.40	0.51	0.63	0.58	0.60
TDN	4.44	4.30	4.85	4.11	3.86	3.87
Deficit/Surplus						
CP	+0.17	+0.03	-0.01	-0.09	+0.56	+0.49
TDN	+1.48	+0.57	+0.32	+0.42	+0.44	+0.57
CROSS-BRED COWS						
Average availability						
DM	8.73	8.56	6.34	11.44	9.61	11.77
CP	0.57	0.49	0.47	0.64	1.18	1.54
TDN	4.53	4.41	3.36	5.94	4.94	6.09
Requirement						
DM	8.75	8.75	8.75	8.75	8.75	8.75
CP	0.56	0.53	0.49	0.83	0.71	0.72
TDN	5.20	5.10	4.72	5.18	4.60	4.62
Deficit/Surplus						
CP	+0.01	-0.04	-0.02	-0.19	+0.47	+0.82
TDN	-0.67	-0.69	-1.36	+0.76	+0.34	+1.47

* 2 kg DM was estimated from grazing in Kharif; ** 1 kg DM was estimated from grazing in Rabi.

Table 5 Income over feed cost from milch animals(INR/animal/yr).

Particulars	Low potential area		High potential area	
	small farms	large farms	small farms	large farms
LOCAL COWS				
Green fodder	123	113	872	1084
Dry fodder	1893	1612	398	387
Concentrates	1412	1268	179	405
Cost of grazing	-	-	-	-
Total feed cost	3428	2993	1449	1876
Annual milk production (l/yr)	1026	930	825	840
Income from milk (INR/yr)	3078	2790	2062	2099
Dung value (INR)	220	220	219	226
Total income	3298	3010	2281	2325
Income over feed cost	-130	17	832	449
CROSS-BRED COWS				
Green fodder	668	NA	1168	1358
Dry fodder	972	NA	427	380
Concentrates	1586	NA	646	777
Total feed cost	3226	NA	2241	2515
Annual milk production (l/yr)	2030	NA	1672	1657
Income from milk in INR	6090	NA	4179	4143
Dung value (INR)	220	NA	263	252
Total Income	6310	NA	4442	4395
Income over feed cost	3087	NA	2201	1880

and reverse in high potential area. In the LPA, value added from livestock is proportionately higher compared to crop value added than in the HPA, where crop value added is relatively more important than from livestock.

A comparison of income from dairy as proportion from the total could not be done due to lack of data on cropping and other activities. With respect to feed cost again there is difficulty to determine how the dry and green fodder should be costed. Only an average price of milk over the year was taken to work out the annual income in the Karnal area. In case of cross-bred cows, the relative income for farmers of low potential area is much higher than from the high potential area. The data for large farmers from Baroda area are not available hence a comparison can be madeonly for small farmers. The difference is clearly caused by a higher annual production of milk in the case of small farmers from the low potential area because of higher concentrate feeding and maintenance of higer producing cows on the farms rather than selling them as in the Karnal area.

CONCLUSIONS

The study shows differences between high and low potential regions in terms of income and feed requirements and production systems. The study suggests that in the low potential area of Baroda suitable supplementation is required to correct the energy deficit of cross-breds. In the high potential area, more efficient utilisation of feed can be achieved either by keeping higher producing animals on the same feed or by reducing the feeding levels per animals. The study also points out limitations with respect to gathering of accurate information on intake in grazing animals. Suitable methods should be developed to provide a better estimate of the intake during grazing and the subsequent nutritive status.

The study reconfirms general observations that animals of small farmers are sometimes better maintained than those of large farmers, except in the case of local cows in low potential areas. In the LPA, income from local animals is lower than for local animals in the HPA. Small farmers in LPA lose money on local animals. In the case of cross-breds, income is higher for small farmers in the LPA than in the HPA. There is still, however, substantial scope to increase productivity and farm income from dairying in both the LPA and HPA. The study will eventually lead to the development of specified extension messages in both the areas.

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SURVEY AND FARMING SYSTEMS RESEARCH AS SEEN BY A NON-GOVERNMENT ORGANISATION LIKE BAIF AND OUTSIDE AGENCIES

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SUMMARY

This paper describes differences in the perceptions, approach, objectives and scope of work of FSR type studies for a Non-Government Organisation (NGO) focussing at development like BAIF, as compared to a strict research approach of other organisations. For BAIF, surveys and FSR type studies are a part of a learning process with multiple objectives. They are to have a close linkage with development and are also meant for monitoring and impact studies of programs, as needed by the sponsoring agencies. It is pointed out that NGO's are peoples organisations with a mission to undertake integrated development with necessary sensitivity for felt needs and perceptions. Thus participatory approaches, a holistic view and need-based program formulation are a natural recourse for the NGO's. Cattle development, which was the first activity, was used as a point of entry and as an opportunity to establish rapport with farmers. It also served to undertake surveys and FSR type studies to learn about the area, the people, their productions systems and the linkages and constraints. The studies need only limited additional expenses and effort. The information is gathered on a continuous basis and it provides continuous information on happenings at the farms. Studies on traditional crop and livestock production systems and on perceptions and involvement of women of different socio-economic strata are taken up in a number of districts to obtain a clearer understanding and formulate more effective extension and training programs.

The paper discusses how a different approach for studies and use of results emerged in view of characteristics, working system and objectives of an NGO like BAIF. An approach best described as socialising and repeated informal discussions was found more effective in gathering information than the use of formats, questionnaires or structured interviews. The use of a multidisciplinary team of specialists, as is usually recommended, was found impractical. Such teams are difficult to establish, and it is even more difficult to find specialists with practical experience and a development orientation. The NGO staff is oriented to keep an open mind and to use a participatory holistic approach. A development NGO is required to take simultaneous action on aspects like critical needs, or to change their approach as soon as is found necessary. It can not wait for a detailed analysis of data and reporting. The paper also discusses the need to think in terms of systematic approach and change the rigid protocols described for FSR studies.

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INTRODUCTION

The NGO movement in Western India, is as old as, and to some extent, related to the freedom movement initiated by personalities like Gandhiji, Tilak, Gokhale etc. Initially, the majority of NGO's were established to take up activities in the field of education and human health, subsequently they became involved in relief work during floods, droughts, epidemics etc. The many NGO's have different characteristics, philosophies and approaches, but their common factor is the objective to work for the benefit of the community.

There are some organisations with religious and political influences and backgrounds. Other common features of NGO's are that most of these are founded by motivated and eminent persons or groups of persons, with a view to undertake welfare or development activities. The NGO's are usually quite sensitive to peoples problems and constraints, they have good rapport in their operational area and they are able to understand view points of the local communities. These organisations have more flexibility compared to GO's and thus are able to change or adopt to needs and conditions.

The advent of development and reseach oriented NGO's is relatively new and it is only since the last 25 to 30 years that such organisations were formed. These NGO's are more professional and believe in application of science and technology for development. Obviously the majority of them are involved in agriculture or agriculture related activities. Unlike the relatively restrictive views and approaches of the earlier NGO's the professionally managed NGO's are more open and flexible in approach as well as spheres of activities. However, each one of them has certain thrust areas. Thus we have NGO's with large involvement in agriculture and livestock production while others with major involvement in training, education, awareness or environmental issues.

Studies on NGO involvement in development and research

The NGO involvement has also become a subject of interest to various development analysts and researchers. Within the last decade or so a number of articles, booklets and books have been published on NGO's and several workshops/symposia were arranged. The publications describe various types of NGO's, variations in their approaches, philosophy etc. The case studies described in the Asian Seminar on Rural Development at Ahmedabad in 1986 show the variation in approaches, philosophies of NGO's. Murthy (1986) reports results of case studies of two NGO's SEWA and Mahiti from Gujarat. He indicates that while both organisations recognised the need for generating source of employment and income, their approaches were different. SEWA believes in direct action and it provides vocation to generate employment and income while Mahiti believed in education and creating awareness amongst people before making available economic activity. Gupta (1986) presents an interesting study on two NGO's from Karnataka i.e. Assifa and Myrada. Both the organisations started with the program of resettlement of families and have done well in achieving this objective. However, Gupta (1986) pointed out clear differences in their philosophy and orientation as well as the style of functioning. Assifa is an organisation which strongly believes in Gandhiism and certain rituals which restricts their sphere of work and apprach as well as adoption of technologies. Myrada is more professional and open in approach. It implements a resettlement program developed approach for rural appraisal for better understanding of production systems and constraints and decide about adoption of appropriate technologies.

The Overseas Development Administration of the U.K. has published a number of papers based on studies about characteristics of NGO's, their involvement in development as well as applied research in several countries. However, these reports mainly discussed GO-NGO relationship with respect to GO-NGO relations varies considerably from country to country depending on the political structure and climate. The ODI network paper (Berdegue, 1990; Aguirre, 1992) based on experiences with Chilean NGO's clearly indicate that the future of NGO's depend very largely on political climate. The conditions in Asian and some Afican countries are somewhat favourable for NGO's and their involvement in the implemention of development extension and research programs, in collaboration with Government Agencies (Musyoka *et al.*, 1991; Mungate and Mvududu, 1991; Khan *et al.*, 1991; Bebbington and Farrington, 1992). Some of these studies indicate limitations of NGO's, lack of coordination between NGO's and the need to develop technical skills and professional approach. As a part of the study, ODI in collaboration with IIED and other organisations arranged regional workshops in South America, West Africa and South Asia in 1991 and 1992. The role of NGO's in technology development, technology transfer, effective extension program and also to some extent, influencing government policies has been pointed out in the workshop.

Some of the analysts indicated that a considerable increase in the number of NGO's and their involvement in the implemention of governments's development programs is partly due to:

a) policies and insistence of International Funding Agencies and
b) changing political situations in some countries (particularly in South America).

In a workshop in Hyderabad (India) some NGO's stressed the need for proper understanding of Government programs and procedures. The workshops recommend greater interaction between GO and NGO's, full utilisation of NGO's ability to promote farmer participation and points of complementarity between the two organisations can be elaborated. The need for developing research capability with farmer participation (on farmers) by the NGO's was stressed in all the workshops (Khan *et al.*, 1991). Other analysts like Rehnema (1985) have cautioned against getting carried away by "the word NGO being considered synonymous with devotion and dedication to development".

The FSR approach

The Farming Systems Research approach is recommended for developing country situations and is said to be more effective in view of some inadequacies of the traditional disciplinary oriented research approach (Raman, 1991). However, while studying papers on FSR, the reader gets into a maze of theories, arguments and counter-arguments with respect to approach, methodology, objective etc. The more one reads about FSR, the more one gets confused over methodological issues (regarding implementation) or over typologies and semantics (Fresco, 1984; Simmonds, 1985; Merrill-Sands, 1986; Wilson *et al.*, 1986; Patel *et al.*, 1993). Most of the articles on FSR methodology prescribe a strict protocol as follows:

- a multidisciplinary team - a group of 5-7 specialists of specified subjects to be associated with the study,
- a five step approach, described as different phases, to be followed before deciding on the introduction of technology, finalising development program and its implementation.

Gibbon (1992b) reviewed Farming Systems Research approaches and points out three problem areas in the implementation, based on the usually recommended methodology. These problems relate to issues pertaining to :

- the focus of FSR on the farm household as unit of analysis;
- the 4 or 5 stage approach to implementation;
- an inadequate understanding of the household definition with respect to gender.

Gibbon suggests a need to study the recent work and approaches like that of Chambers (1983), farmers first approach or agro systems analyse suggested by Conway (1985) and informal research and experimentation recommended by Biggs (1980) and Chand and Gibbon (1990). Gibbon (1992a) strongly recommends involvement of NGO's in FSR type of work in view of their effectiveness and close association with the community.

Rangnekar *et al.* (1990) in a review on the initial FSR type studies undertaken by the BAIF, pointed out problem areas with regard to the concept and methodology of FSR, as is usually recommended by the FSR protagonists. They have multiple utility and a more flexible approach needs to be adopted.

BAIF AND FSR

The BAIF was established in 1967 by Manibhai Desai. He was a close associate of Gandhiji on whose advise Manibhaiji became involved in village upliftment work. Thus BAIF's background is influenced by the Gandhian approach and Manibhaiji's experience of village upliftment. The development activities of the BAIF started in 1969 in Western Maharashtra and South Gujarat, with Cattle Development Program. BAIF's involvement now extends to five states, i.e. Maharashtra, Gujarat, Rajasthan, Uttar Pradesh and Karnataka.

BAIF's mission is to create, especially for the disadvantaged section, opportunities for gainful self employment for rural families, sustainable livelihood, enriched environment, improved quality of life and good human values. This is achieved through developmental research, effective use of local resources, extension of appropriate technologies and upgradation of skills and capabilities with community participation.

Cattle development happened to be the first project to be approved by Government of India and was taken up in several States. This was followed by activities in the field of agro-forestry, waste land development, tribal development, soil and waterconservation, drinking water programs, fruit plantation and other such activities that were planned on the basis of felt needs, people's perceptions and feasibility. Thus cattle development proved an entry point in most of the project areas (Rangnekar, 1989). The cattle development program provided a base to establish rapport with the rural families and to undertake studies (Farming Systems Research) in order to get a complete picture of the area, the people, their production systems, perceptions, felt needs etc. One example of such work is presented in this workshop by Gahlot *et al.* (1993). These studies were carried out as a process of learning for proper planning and effective implementation (Rangnekar *et al.*, 1990).

Some of the major studies undertaken by BAIF are reviewed below:
- Economics of keeping cross-bred cattle in selected areas of Gujarat, Maharashtra and Rajasthan. This study was conducted between 1982 to 1984 at a few centres in the above mentioned studies involving farmers keeping cross-bred cattle. The study was sponsored by the National Bank for Agriculture and Rural Development (NABARD) and involved economics of rearing, breeding cross-breds and milk production (BAIF, 1989).
- Utilisation in cross-bred bullocks by the farmers at some centres of Maharashtra and Gujarat. This study was carried out in 1980s at a few centres in these two states to understand farmers experience and perception regarding use of cross-bred males for various farm operations (BAIF, 1987).
- Area and family survey for dairy cattle development program initiated during 1984-1985 through the development project sanctioned by the State Government. This study aimed to gather baseline data with respect to assets owned by farmers from various socio-economic groups and regions of Gujarat, their farming practices, feeding and management practices of livestock and productivity of dairy animals. This was followed by setting up of field recording system to get information

regarding performance of local animals as well as cross-breds. Initial results have been reported by Rangnekar *et al.* (1990).

The experience of initial surveys leads to the development of a different approach to carry out farming systems type studies. As a part of BIOCON activities, but also outside BIOCON, a number of studies were done to get in depth information regarding traditional practices, feed resources, various livestock production systems, women practices, feed resources, various livestock production systems, women involvement, indigenous knowledge etc. such as:

- Goat production systems in Mewad region of Rajasthan (Rangnekar *et al.*, 1991b). The studies enabled better understanding regarding the prevailing goat production and marketing systems, identification and prioritization of constraints as perceived by the goat owners and planning of suitable development programs.
- Animal feed resources and feeding practices of dairy cattle, buffalo and goats in tribal areas of Gujarat and Rajasthan (Rangnekar *et al.*, 1991a; Rangnekar and Sharma, 1992; Rangnekar, 1992a). These studies aimed to develop farmer friendly animal feeding systems based on traditionally used material, animal productivity and need for supplementation. The recommendations thus made were found to be more easily adopted.
- Women involvement in Dairy production (Efdé, 1988 ; Rangnekar, 1992b, c). These studies aimed to better understand women perceptions, involvement, decision making and knowledge. The results enabled the modification of training and extension approaches.

Special features of FSR type studies and surveys taken up by the BAIF

The studies and surveys carried out by the BAIF have special characteristics with regard to objectives, approach methodology as well as manner of use of information. A few salient aspects with respect to FSR studies conducted by research organisations and the BAIF are discussed hereunder, and therefore the reference is mostly to the Indian situations:

- Objectives of the studies: for the BAIF the objectives are multiple. They start from a study of Farming Systems, as existing at a given time, to monitor of the project, to learn about the indigenous knowledge, to orient and train the staff, to make extension more effective and to chose, test and develop technologies. In the case of research organisations, the main objective is to support to agricultural research (Raman, 1988; Raman and Balguru, 1990).
- Linkage with development programs: the cattle development work was started to provide the base and entry point even though studies showed that farmer priority and felt need was different (Gahlot *et al.*, 1993). However, the rapport

established through cattle development work enabled BAIF to undertake the studies without much difficulty.

- Learner and Participatory approach: this is a natural recourse for the BAIF staff, but hardly any mention is found in research organisations proposals. Such an approach necessitates a good rapport with farmers, an understanding of their perceptions, giving due weightage to their priorities and felt needs. Hence socialising and arranging repeated informal discussions with farmers is the methodology now adopted by the BAIF, after initial experience with formal surveys and structured interviews.
- Women Involvement: it is recognised that women play an important role in agriculture and particularly in animal production, but their role is often neglected in research and development planning (Swaminathan, 1990). The neglect is noticeable even in FSR studies and some of the gender related issues (Poats *et al.*, 1992). In the BAIF programs of livestock development, the staff was quick to realise that women involvement is critical. Studies were done understand their role, perceptions and felt needs. The studies have helped to modify extension and training programs of the livestock development project to suit the conditions (Rangnekar *et al.*, 1991b, c; Rangnekar, 1992b, c).
- Duration of FSR Studies: the FSR Studies and Surveys do not have periodicity in which only one time effort is made, as is usually seen in the projects of research organisations. In BAIF projects there is a continuous feed back from the field after initial surveys and study. The observations are supplemented by field recording which provide detailed picture of happenings on the farms (of the farmers). The studies are considered a part of a routine operation and working system. Unlike in many research organisations, these are not treated as separate research project Production systems undergo continuous change - being influenced by a variety of factors. Hence a continuous feed back over an extended period of time helps to modify interventions. Feed back is also helpful in monitoring the progress and impact of development program.
- Multidisciplinary teams: a group of 5-6 specialists is often prescribed for FSR or RRA etc. This was attempted initially but found impractical for two major reasons. Firstly it is difficult or impossible to get multidisciplinary teams to cover various project areas and specialists are not likely to spend enough time for in depth study. Secondly it is very difficult to get a team of specialists that have a development orientation and that can overcome their bias of their specialisation. The problem is similar with professional surveyors. It was therefore decided to involve BAIF staff. Fortunately most of the staff have graduated, with courses in rural economics, sociology, extension, alongwith agriculture and animal husbandry. Soon after enrolment, they are oriented towards development, extension, participatory approach, taking a holistic view and reducing their technical bias, as a part of orientation and training. Further orientation and training is given while developing survey and FSR type studies. Their

orientation is not difficult, since most of them are from rural areas and farming background and hence appreciate farmer perceptions and view points. The concept of a systematic approach is more important to the organisation rather than the protocols. Bawden (1992) and Gibbon (1992) have also stressed the importance of developing a systematic approach and thinking rather than being too concerned about prescribed protocols for study.

- Simultaneous action: this has been necessary in many cases while the study is in progress. In many areas the problems can be identified or pointed out by the farmers soon after the rapport is established. And it is noticed by the staff soon after they settle in the area. Action is immediately taken, without waiting for different stages of FSR to be over and for report preparation. Drinking water, rain water harvest, women training, vaccination of animals such as for *Haemorrhagic septicaemia*, runderpest, foot and mouth disease, enterotoxaemia and deworming are a few such examples.
- Additional studies related to social factors: traditions are common out in the project and an essential part of process of learning to improve effectiveness of the development and extension programs. Social factors are not given desired weightage in many FSR's. The perceptions, view points, resistance to change with underprivileged communities can only be appreciated after such studies. Studies carried out with various tribal groups, pastoralists have been very useful. Many of their traditional systems of animal treatment were found to be sound and not only worth preserving but even worth propagating (Rangnekar, 1992; Rangnekar, 1993). Improvements recommended in feeding dairy animals based on traditional systems and material were found to be easily accepted. The recommendations were made after a critical study of productivity, nutritional status and feed resources (Rangnekar *et al.*, 1991c; Rangnekar, 1993).

LESSONS LEARNT

The experience of the last 7-8 years of field studies, some of which are listed above, provided useful information as well as lessons with respect to methodology of studies, compilation of results and their utility. The majority of these aspects are indicated while discussing features of FSR types studies taken up by the BAIF. However, it would be worthwhile mentioning a few points again and or specifically with regard to lessons learnt for future.

- for a NGO like BAIF that is involved in integrated rural development programs, the FSR type of studies are viewed with a multiplicity of objectives. These aspects should be made very clear to outsiders and particularly those from research institutions. The studies are therefore to be designed, implemented and results used accordingly.

- the use of survey formats needs to be avoided, while conduction surveys with farmers. However, designing and pre-testing of formats, for purposes of guidance and reference of the field staff, will be necessary. It is necessary to use local vocabulary and to reduce the number of questions as far as possible.
- while staff orientation and training in conducting surveys is necessary, it is even more necessary to create situations where the results of study are utilised by the staff and considered necessary, as a part of learning process and thus the staff gets sensitised.
- for sampling, proper stratification to cover even the underpriveliged and poorest of the poor groups, need be ensured.
- socializing and repeated informal discussions are the processes found most useful and effective in the gathering of information. Linkage with development programs and the carrying out of these studies after establishment of rapport with the farmer is advisable. It is also advisable to involve field staff rather than hired surveyor engaged for a short period of time.
- continuous interaction between village level staff, the gathering of information, the regional staff, rechecking of the information and the computer centre staff or statistician and other senior officers compiling and analysing the data, is essential.
- the type of studies discussed above are carried out on a continuous basis in order to understand changes over a period of time as well as to monitor the progress of the project. They should thus not be viewed with a short term perspective. On some aspects simultaneous action would be necessary, wherever desired type of technologies are available to overcome the constraints.

CONCLUSIONS

The NGO's differ with regard to extent of involvement in activities, basic philosophy and approach, but all of them have the common goal of working for welfare of the society. There is increasing involvement of NGO's in development and applied research, pertaining to agriculture as well as other fields and more and more NGO's are taking a professional approach.

The planning and implementation of development program requires thorough understanding of the area, the people, their tradition, perceptions and linkages. Participation of the people at all the stage is essential for success of the development effort. Thus detailed studies in any form are necessary for GO's as well as NGO's. However, for NGO's surveys and FSR type of studies which are usually recommended for the support of development and extension could be done with different approaches and multiple objectives.

The survey formats and questionnaire have to be carefully designed, properly pretested and used only as guidelines for the field staff. For proper collection of information, an approach of socialisation and repeated informal discussions is far more effective.

The studies are to be a part of process of learning crucial for persons involved in extension and development program implementation. Proper stratification for sampling based on agro-ecology and socio-economic conditions are necessary to provide desired information. Voluminous data collection can thus be avoided.

Continuous interaction between field staff who is gathering the information and senior staff involved in compilation and data analysis is necessary. Qualitative information is as important for the development agencies as the quantitative information. Sensitisation of the staff at all levels and creating need for learner approach is crucial from all angles.

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SESSION TWO

NUTRIENT EVALUATION AND FEED REQUIREMENTS

NUTRIENT EVALUATION AND FEED REQUIREMENTS

It is commonly understood that (Asian) farmers have been feeding their animals since centuries on grass from forest, roadsides or on byproducts from cropping, like straws, brans or cakes. Maybe it is more correct however to say that in those systems animals have mainly fed themselves. The animals used to collect whatever was available and they even selected the parts in the feed that they liked best. Whatever the animals produced was a welcome and often essential contribution to the survival of the family.

When feed supplies and demand patterns for animal produce changed, the farmer, his wife or their children increasingly had to assist the animals in meeting their daily feed requirements. In that way, farmers started to design feeding systems based on experience and local availability of resources. Those feeding systems are changing and farmers adjust by either growing and buying extra feed, or by reducing the herd strength or changing herd composition. Sometimes farmers in many farming systems even prefer to allow the production of the animal to decrease seasonally in order to adjust to feed availability. Those farmers know that it is not always economically attractive to aim for high production per individual animal. Often it may be necessary to accept lower production per animal, especially in farming systems with low fixed costs and no remunerative prices for the produce.

Even the value of "produce" is not a static concept, as demand patterns may change. Survival at below maintenance rations is an important form of produce in many Indian systems but in areas where milk marketing has started, the milk may become much more important than it ever was. Milk becomes a tradeable commodity in systems where it was traditionally only given away or where ghee used to be the major endproduct. An old North Indian saying is that "selling the milk is like selling your son", or "when you sell milk, the cow will get sick". In many systems, draught or even dung production is the most important form of produce, though that is likely to change with the introduction of fossil fuels for tractors and fertilizer. Considering the uncertain long-term supply of these inputs, it may be unwise however to discard draught power and dung production alltogether. In areas with prolonged droughts, the mere survival of an animal can be counted as a form of produce.

Changing feed supplies require that the farming community understands the basics of animal nutrition whether by practical experience or aided by laboratory experiments. This led to the "science of animal nutrition" which can support the farmers' "art/experience of animal nutrition". Scientist have done much work over the past century to develop systems of calculating feed requirements and analysing nutritive value. Since most of this work was done in Western countries, the concepts have to be applied with care in non-Western feeding systems.

Traditional scientific systems of feed evaluation considered mainly digestible energy or TDN, digestible crude protein, mineral, vitamin and water requirements related to maintenance and production of the animals (discussed by Ranjhan and Kiran Singh). The feed analysis was based on the so-called proximate analysis which analyses organic matter, crude protein, crude fat, crude fibre and nitrogen free extract. Newer systems include a better fractionation of the fibre, prediction of rate and extent of digestibility in vitro and in sacco of various feed fractions. Prediction of dry matter intake and selective consumption is an increasing concern of animal nutrition research, including attention to anti nutritive factors (the paper by Ranjhan). New concepts on protein nutrition require better understanding of (degradability of) various protein fractions (as discussed by Sampath et al.*). The relevance of protein fractions is not so simply understood in practice and depends among others on the level of production (see Walli* et al.*). Protein, energy and mineral nutrition cannot be seen in isolation and the ratio of protein to energy is more and more used, taking into account the level of production by the animal. The rumen and the feed are complex systems with many interactions, which need to be studied in greater detail. The advent of personal computers makes it possible to study the interactions and the relative importance of the factors involved, in order to predict responses (see Singh and Oosting, and Singh* et al.*).*

Much information can still be generated on feed evaluation and nutrient requirements, but much is already available. A large number of experiments provide data sets as reviewed by Prasad et al*. Those data are highly variable but can be used as a basis for ration formulation. Here again the advent of personal computers makes it possible to develop simple models that predict (trends in) animal responses (see Joshi* et al.*). The results of model calculations should not be taken as a precise answer, and the reliability is only as good as the data and models that are used. Results of modeling excercises also should be thoroughly checked against field practice, common sense and experimental results. The major use of such models is that:*
- *they predict the results of changes in the systems which are difficult or expensive to be determined by sufficient experiments,*
- *they establish likely problems in animal nutrition,* i.e. *they can (re)direct research priorities,*
- *they can be used for training of extension workers, who face different problems in a variety of farming systems.*

Much debate takes place on the usefulness of feeding standards. Many past publications looked too much at requirements of animals for types and levels of production that were alien to tropical and/or resource-poor farming systems. This could lead to recommendations which replace straw (often the most abundant resource), by including lucerne or other non-available feeds.

Feeding standards have to be applied with common sense. The final criteria for the farmer to adopt a feeding system is not based on only biological parameters (high live weight gain, milk *production) but on economics. However, farmers' sense of economics is difficult to quantify and quite often different from the concepts of conventional economic teaching. Moreover, farmers do not speak or think in terms of protein or metabolizable energy, but in terms of animal response. Effective extension needs to take into account the farmers mode of communication in this respect. Traditional feeding practices evolve from practical experience. They should not be ignored but improved with scientific knowledge according to (changing) resource availability which determine the optimal feeding systems. Animal nutrition workers cannot operate in isolation from economists and (of course) farmers. In many areas livestock is kept as only one or a secondary component of farming besides cropping or even off-farm labour. It implies that livestock feeding regimes are also to be established while taking the cropping pattern into consideration. Models, tables with feed evaluation and requirements are "tools" to understand those systems better. They can be useful to assist, rather than to replace farmers/ scientists common sense.*

RECOMMENDATIONS FOR NUTRIENT EVALUATION RESEARCH

There is a need to determine RDP and UDP values of a large number of conventional and non-conventional feeds, combined with a study on their relevance and methodology. Dietary RDP/ UDP ratios need to be established with respect to production response on fixed/ variable energy levels, for cross-breds, buffaloes, specifying the differences between tropical and temperate regions.

Passage rates for different dietary combinations of roughage, concentrate, greens etc., need to be established in order to better assess the values of degradability.

Other nutrient analysis that are relevant for fibrous feeds include estimation of fibre-bound-N and pepsin-insoluble-N of low degradable feed in nylon bags. Metabolisability of feeds and ME requirements are to be established wherever possible, with determination of MFN. It is important to establish reliability of gas production, and relate gas production with DMD, OMD, and DMI etc. to develop prediction equations for different substrates.

The effect of N and mineral supplementation of forages/straws on DMI, substitution rates and associative effects is to be studied. Existing data on nutritive values DMI, CP, OMD, are to be compiled and put into a database. In that way they can be used in management models such as the cow model as presented during this workshop.

The validity and objectives of ration formulation are to be established, in order to develop practical feeding systems, nutrient requirements and feed formulation.

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NUTRIENT REQUIREMENTS, FEEDING STANDARDS AND FEEDING OF RUMINANTS AND THEIR RELEVANCE TO INDIAN CONDITIONS

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SUMMARY

Various feeding standards are compared and analysed in this paper, namely, those of the National Research Council (NRC) in United States of America, the Agricultural Research Council in the United Kingdom, and of the Indian Council of Agricultural Research in India. The discussion is related with the fact that the majority of Asian farmers, including those from India, feed their animals as per their experience, which seems to be at odds with the so-called scientific feeding standards, developed after extensive research in laboratories and research stations. In the foreseeable future it is envisaged that farmers will continue to depend on local feed ingredients (straws, stovers, natural grasses and limited quantities of byproduct concentrates) for the feeding of their livestock. There is a lack of information on the production responses of animals in different feeding systems based on local feed ingredients as available to the individual farmers, often insufficient to achieve maximum biological yields. The response of graded levels of concentrates or legume supplements to straw based or grass based rations of growing, lactating and work animals to optimize production needs to be further understood and tested under farmers (cost) conditions. The farmers objective is to achieve a production level that is economically attractive.

INTRODUCTION

The practical feeding of (Indian) animals is based on methods which relate the nutrients required for different physiological functions, to estimates of the nutrients which the animal can extract from different feeds. Nutrient 'requirements' can be defined as the amounts which must be supplied in the ration to meet the needs of the normal healthy animal. Both the 'need' and the 'normal healthy animal' are often ill-defined but they can range from high to low levels of production per animal, according to farmers resources (Jackson, 1981; Schiere and De Wit, 1993). The methods which are used to relate feed to requirements are usually referred to as 'feed rationing systems', while the requirements for specific nutrients when set in the tables are known as 'standards'. This paper only considers the energy, protein and dry matter intake. Information on minerals, vitamins

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and water is not discussed here, but elaborated in standard international textbooks and publications such as Crampton and Harris (1969) and McDonalds *et al.* (1981). Relevant Indian handbooks are those of Ranjhan (1990) and Ranjhan (1993a, b).

Different countries have evolved their own standards, based on experiments conducted with farm animals in the agro-climatic and economic conditions prevalent in the country (De Boer and Bickel, 1988). These conditions can affect the objectives of the farmer, the feeds available and the requirements of the animal, which in turn will affect the emphasis that needs to be placed on different components included in the rationing systems. Thus, since there is a wide range of agro-ecological conditions within India (Jain and Dhaka, 1993), any rationing system will need to be modified according to the degree of intensification of production, the local climate and the types of feed and animals available locally. The standards that are developed in the various research centres, are updated from time to time, based on latest experimental results. Requirements are published in tables for use in practical conditions (ARC, 1980, 1984, 1988, 1990; NRC, 1984, 1987, 1988).

In the U.K., a technical committee was set up in 1959 by the Agricultural Research Council (ARC), charged with the responsibility to review periodically the literature on the nutrient requirements of various classes of stock and to make alterations that were deemed necessary in the published feeding standards. The results of this committee were published in two forms:

- technical reviews which contain all the details about the data on which the calculation of the requirements have been based, as well as the methods of calculations that have been adopted (ARC, 1980, 1984);
- summaries of the sections which give only the estimated requirements without details of the methods by which they have been derived.

More recently the ARC, now renamed the Agricultural and Food Research Council (AFRC) has been publishing updates of these requirements in Nutrition Abstracts and Reviews (Rook, 1991).

In the U.S.A., the Committee on Animal Nutrition under the auspices of the National Academy of Sciences - National Research Council and the US Department of Agriculture has been publishing the Nutrient Requirements for around fifteen types of farm animals since 1945. Two recent special issues are dedicated to intake (NRC, 1987) and protein (NRC, 1988). The early reports on nutrient requirements of dairy cattle were published as Recommended Nutrient Allowances for Dairy Cattle. They were used upto 1964 and gave a margin of safety in all cases. After 1964 the Committee considered nutrient requirements to provide maintenance, optimum production and prevention of all symptoms of nutritional deficiency. It is significant to note that both NRC and ARC give requirements for several production levels, i.e. not only for high biological yields that are not always economically attractive (Schiere and De Wit, 1993).

The latest requirements which are now published for dairy cattle (NRC, 1988) are designed to meet the needs of animals that have higher than average requirements for essential nutrient. Thus the requirements are higher than average and in this respect, they provide a margin of safety for animals whose requirements are average or below average. The NRC recommendations present requirements for both large and small breeds as well as for males and females. By and large these recommendations are being followed in many countries outside U.S.A. The latest requirement of 1989 for dairy cattle have been compared in this paper with the ARC (1980) values and those of Sen *et al*. (1978) that were developed for India.

In Asia there are not many standards or requirements which could be compared with either NRC or ARC for protein, energy, minerals and vitamins, though the work of INFIC in this area needs to be mentioned. Recently, tables with nutrient values and requirements are published in Sri Lanka, Malaysia, Indonesia (Ibrahim, 1988; Devendra, 1979; Hartadi *et al*. 1980).

In India, during the last four decades, serious efforts have been made to develop feeding standards. Sen (1956) proposed the nutrient requirements for dairy cattle by taking mid-range values given by Morrison (1956). These data were revised by Ray (1964) and Ray and Ranjhan (1978) based on studies of basal metabolic rates, mostly conducted at IVRI-Izatnagar and feeding trials conducted at other research stations of the country. In 1978, the starch equivalent system for expressing energy values was dropped from the publication (Sen *et al*., 1978). The TDN system for expressing the energy requirements (total digestible nutrients) was however retained. The requirements were further revised by Ranjhan (1990) and the ME system was also introduced. The ICAR also published the Nutrient Requirements for cattle, buffaloes, sheep, goats, camels, poultry and swine (ICAR, 1985). The publication of Kearl (1982) on nutrient requirements for the developing countries was partly based on such Indian work.

GENERAL CONSIDERATIONS ABOUT FEEDING STANDARDS

Standards can be based on farmers experience, or on feeding trials in research centres. This leads to confusion about terminology and objective of production.
The terminology on feeding value based on laboratory assessment uses crude protein, degradability, organic matter content, whereas farmers express feeding value in terms of effect on butterfat content, lustre and general appearance of the animal, waste/ intake, etc. (Rangnekar, 1993). The objective of production at experimental stations is generally to achieve high individual animal responses. This attitude is based on production situations in farming systems of high input use, that are common in western countries, or near urban centres in the tropics, but not in low input farming conditions. The fact that in this paper

we discuss requirements for animal draught rather than for beef production, illustrates that the objectives of the Indian animal farming system are different from those in for example the U.S.A. and the U.K. Nutrient requirements can be expressed in either absolute terms as quantities per animal per unit of time, or in relative terms as nutrient concentration in the feed. This paper discusses the nutrient requirements for dairy cattle in view of their importance for livestock development in India and related farming systems.

Nutrient requirements for dairy

The three standards reviewed in this paper are NRC (1988), ARC (1980) and those of Sen *et al.* (1978). The first two standards were formulated for animals raised under temperate conditions with high quality feeds. The Indian standards were developed under tropical conditions with low producing animals raised on poor quality forages. The work at IVRI has shown that Indian cattle and buffaloes have lower basal metabolic rates than temperate breeds and consequently lower maintenance requirements. Careful definition of systems is however necessary, since a vast country like India covers tropical as well as temperate situations. It is also not sure whether these differences occur due to breed or due to feeding and farming systems. Papers on nutritional requirements of buffalo etc. are in the Proceedings of the Animal Nutrition Society of India Meeting at Bangalore (ANS, 1991). The nutrient requirements given by ARC were mostly derived from calorimetry experiments, while the NRC data are based on comparative slaughter experiments. Sen *et al.* (1978) initially used values from Morrison (1956) but revised the requirements by using feeding trials.

Dry Matter Intake (DMI)

The willingness, or ability, of an animal to consume a particular feed is a key factor in determining the amount of nutrients which it will supply to the animal. Dry matter intake increases with liveweight nonlinearly as described for a range of liveweights in Table 1. The feed intake of ruminants is influenced by many factors, including feed characteristics, animal species, physiological state, ambient temperature and management practices and thus is very difficult to predict. Several workers have tried to predict intake either empirically or from biological parameters (Forbes, 1986; Ketelaars and Tolkamp, 1991; NRC, 1987). These predictions are generally based on intakes measured under controlled experimental conditions rather than on on-farm intakes. The purpose of this section is not to discuss how these factors may affect prediction, but to give some indication of the maximum intakes likely to be achieved by cattle of different liveweights and in different physiological states.

NRC (1988) uses the term 'requirements' to describe estimates of DM intakes, although any 'DM-requirement' must be dependent on the energy and protein content of the feed. The intake requirements referred to here are therefore considered to be the maximum DM intakes predicted by the different systems (Table 1). There is a reasonable degree of agreement between predictions, particularly for mature animals. These estimates are generally for high quality feeds, the intakes of feeds imbalanced in energy:protein or with a high fibre content may be lower.

The estimates of DMI for cows weighing between 400-800 kg and yielding between 10-60 kg of 4% FCM have been given by the NRC (1988). The ARC (1990) gave the DMI based on the live weight, metabolizability of the dietary energy and the proportion of the concentrate in the diet. Under this system the feeds are first divided into coarse and fine categories and animals are divided categories of sheep and cattle. Coarse diets consist of long and chopped roughages (including grazed herbage) with or without concentrates. Finer diets consist of concentrates and/or milled or wafered roughages, alone or in combination. Lactating cows eat 35-50% more than the non-lactating cows of the same weight and on the same diet. A good relationship also exists between the yield potential of individual cows and their maximum intake. However, within a lactation, DM intake increases slower than milk yield, with peak intake occurring some weeks after peak yield.

Standards are made for different levels of production related to maintenance. But to cite an example of how temperate and tropical standards compare, an average non-lactating dairy cow of 500 kg body weight has been taken. The predicted dry matter intake at 500 kg are similar between NRC, ARC and ICAR standards. Also, in animals of 200 kg LW growing at the rate of 500 g/day, predicted DMI appears to be similar with a variation of only 8-10%.

Energy Requirement

Early rationing systems used in Europe compared feeds to one standard feed, initially hay, later replaced by starch. The starch equivalent or SE system was adopted in India in 1912 and, only replaced by the TDN and Metabolizable Energy (ME) system in 1972 on the recommendation of the Second Animal Nutrition Research Workers Conference and the Scientific Panel of Animal Nutrition and Physiology of the Indian Council of Agricultural Research. The ME system was developed in the U.K. by Blaxter and adopted by the ARC in its Technical Review published in 1965. In the U.S.A., feed rationing for ruminants is also based on energy but the standards are expressed as Net rather than Metabolizable energy, the difference being heat (NRC, 1984, 1987, 1988). Since the efficiency with which ME is used differs between animals in different physiological states, separate values for NE need to be given for lactating and growing animals. The tables of feed values are therefore more cumbersome, although once these have

Table 1. Daily nutrient dry matter requirement of growing dairy cattle and mature bulls

Live weight (kg)	Gain (g/day)	NRC (1989) (kg/day/animal)	ARC* (1980) (kg/day/animal)	ICAR (1985) (kg/day/animal)	Ranjhan (1990) (kg/day/animal)	DMI (% of LW)
Small breed growing males						
100	400	2.41	2.8	2.75	2.6	3.0
150	400	3.31	-	3.90	3.8	2.5
200	500	4.24	4.3	5.02	5.0	2.5
250	500	4.99	-	5.97	6.2	2.5
300	500	5.89	5.6	-	7.0	2.5
350	500	6.86	-	-	7.0	2.0
400	500	7.90	6.8	-	8.0	2.0
500	500	10.28	7.9	-	-	-
600	500	13.25	8.9	-	-	-
Maintenance of mature breeding						
500	0	9.09	9.0	9-10	9.0	1.8
600	0	10.43	10.1	11-12	10.8	1.8
700	0	11.70	-	-	-	-
800	0	12.94	-	-	-	-

Notes:
* Metabolizability of the energy of diet = 0.5

been obtained, the system is easier to use. A number of new systems for feeding ruminants have been proposed since 1962 when the Metabolizable Energy System was introduced. These include Californian Net Energy (fattening) system (Schieman *et al.*, 1974), the Net Energy System of Flatt *et al.* (1968, 1972).

The use of TDN has been retained in India, since these values are available for a wide range of feeds. Measurement of ME is more difficult (Ranjhan, 1993) but it can be predicted from TDN (1 kg TDN = 4.409 MCal DE; ME = 0.81 * DE). However, such equations are only approximations and they further compound the errors associated with the use of TDN as described by Ranjhan (1993). There has been some criticism about the use of TDN and DE as a measure of useful energy of feeds because both these measures tend to underestimate the value of concentrates relative to forages (Moore *et al.*, 1953). Calorimetric studies have shown that non-lactating animals use DE and ME for maintenance and body gain with different degrees of efficiency. For this reason NE values have been used. However, for comparison with Indian standards, only TDN and ME values have been taken in this paper.

Energy requirements are compared in Tables 2, 4 and 5. The energy requirement proposed by NRC (1988) and ICAR standards (Sen *et al.*, 1978) for growth and maintenance of breeding bulls are comparable with a difference of 8 - 10% on either sides at different growth rates. This can be understood since Indian standards have been computed only on one standard growth rate of 500 g per day from 6 - 36 months where as temperate standards are more exact and have been calculated with growth rates. For maintenance, Sen *et al.* (1978) and Ranjhan (1990) used 120 Kcal ME per kg metabolic weight for estimating ME requirement for maintenance of Zebu cattle, cross-bred cattle and buffaloes based on the Indian work of Katiyar (1972), Krishna Mohan *et al.* (1975) and Patle (1973). The ARC uses 121 and the NRC uses 129 Kcal/$W^{0.75}$ which are not very much different. Similarly for milk production the requirements are given.

Protein Requirement

Traditionally, the most used method in India to express the protein requirements of ruminants is the digestible crude protein (DCP). This system is still followed widely, but critically reviewed by Walli *et al.* (1993). The DCP method gives too much weight to non-protein nitrogen (NPN), relative to intact protein. Therefore, the Committee on rationing of dairy cows (1925) proposed the adoption of a Protein Equivalent, that is, 0.5 * Digestible Crude Protein, where NPN was assumed to be fully digestible but to have only half the value of Digestible True Protein. This protein equivalent under-estimated the value of non-protein nitrogen in silages (Evans, 1960) and the use of DCP values was again proposed. The responses obtained from varying DCP intakes are influenced by the source of protein and energy

Table 2. Daily energy requirements of dairy cattle and mature bulls

Live weight (kg)	Gain (g/day)	NRC (1989)		ARC*	Sen et al. (1978)	ICAR (1985)	Ranjhan (1990)	
		ME (MCal) Small breed	TDN (kg) Growing males	ME MJ/d	TDN (kg)	TDN (kg)	TDN (kg)	ME (MCal)
100	500	6.54	1.72	29 (6.9)	1.9	-	1.9	6.8
150	500	8.55	2.25	-	2.6	-	2.6	9.4
200	500	8.55	2.25	45 (10.7)	3.0	-	3.0	10.8
250	500	12.31	3.27	-	-	-	-	-
300	500	14.15	3.77	59 (14.0)	4.0	-	4.0	14.4
350	500	16.01	4.29	-	-	-	-	-
400	500	17.91	4.82	71 (17.0)	5.0	-	5.0	18.1
500	500	21.93	5.98	83 (20.0)	-	-	5.0	18.1
600	500	26.50	7.29	94 (22.4)	-	-	-	-
Maintenance of mature breeding bulls								
500	0	15.79	4.34	61 (14.5)	4.5	4.45	4.5	16.2
600	0	18.10	4.98	70 (17.0)	5.4	5.35	5.4	19.4
700	0	20.32	5.59	-	-	-	-	-
800	0	22.46	6.18	-	-	-	-	-

Notes:
- * Metabolisability of energy of diet = 0.50, 1 calorie = 4.184 joules
- Figures in parenthesis are calories

supply, besides other factors (Walli *et al.*, 1993; Sampath *et al.*, 1993). ARC proposed in 1965, that protein requirements be expressed as available protein, i.e. the amount of crude protein of defined biological value that would have to be absorbed from the digestive tract to meet the calculated requirements of the tissue for maintenance and production. During the same year it was recognized that the Biological Value (BV) of protein in ruminant feeding varies with the nature of the feed. The BV is determined by the extent to which the amino acids from microbial protein formed in the rumen are supplemented by those from undegraded protein. Therefore, a new approach was proposed by Nolan and Leng (1972). In ruminants, the need for the tissues are met by amino acids absorbed from the small intestine. Those amino acids originate partly from the dietary protein which has escaped fermentation (Rumen Undegradable Protein or Bypass Protein) and partly from the microbial protein formed in the rumen. Degradability of dietary protein in the rumen varies according to protein sources and processing techniques (Sampath *et al.*, 1993). Increasingly, the nitrogen (and micronutrient) requirements of the rumen micro-organisms was understood, and in the U.S.A., Burrough et. al (1975) proposed the Metabolisable Protein System. Protein requirements are compared in Tables 3, 4 and 5. Both the ARC (1990) and the NRC (1988) now express the protein requirements as Rumen Degradable Protein (RDP or DIP) and Rumen Undegradable Protein (RUP or UIP). Extensive data are now available from the U.K., the U.S.A. and other countries on RDP and RUP (NRC, 1988). This system has not yet been widely adopted in India and DCP is still continued to be used. However, a few laboratories (IVRI and NDRI) are now working in this area and in a near future these requirements too would be worked out for India. The details about the protein systems have been discussed in this workshop by Sampath *et al.* (1993) and Walli *et al.* (1993).

Nutrient Requirements for Working Cattle

There is no requirement for working cattle and buffaloes proposed by NRC nor ARC. Kearl (1982) proposed the requirement for working cattle and buffaloes based on the Indian standards of Sen *et al.* (1978) (Table 6). No significant difference between the two standards is apparent. More recent work about nutrient requirements for working cattle is reported by Lawrence *et al.* (1993) and by Teleni and Murray (1991).

RELEVANCE OF FEEDING STANDARDS IN FEEDING FARM ANIMALS IN THE VILLAGES

Village animals in India are fed mostly on straws/stovers and other crop residues along with little bit of grazing or cut and carry grass. Lactating animals sometimes receive additional concentrate feeds consisting of only cakes (mustard, groundnut,

Table 3. Daily protein requirements of growing dairy cattle and mature bulls (g/day)

Live weight (kg)	Gain (g/day)	NRC (1989)			ARC (1980)		Sen et al. (1978)		ICAR (1985)	Ranjhan (1990)	
		UIP Small breed	DIP Growing males	CP	RDP	UDP	DCP	CP*	DCP	DCP	CP
100	500	287	41	392	240	15	280		328	280	400
150	500	257	129	525	-	-	350		442	350	500
200	500	232	213	573	365	-	400		556	400	555
250	500	210	296	598	-	-	470		-	470	671
300	500	193	378	707	470	-	-		-	-	
350	500	180	461	823	-	-	480		-	480	700
400	500	171	545	947	570	-	-		-	450	-
500	500	166	634	1083	665	-	-		-	-	-
600	500	187	93.3	1590	750	-	-		-	-	-
Maintenance of mature breeding bulls											
500	0	161	472	789	420	-	450		278	450	650
600	0	155	573	905	475	-	530		336	530	890
700	0	148	670	1016	-	-	-		-	-	
800	0	142	764	1123	-	-	-		-	-	

Note:
- * Assuming 70% digestibility of the combined ration

Table 4. Daily nutrient requirement for maintenance

Live weight	NRC (1989)			Sen et al. (1978)			ICAR (1985)		Ranjhan (1990)		
	CP (g)	TDN (kg)	ME (Mcal)	DCP (g)	TDN (kg)	ME (Mcal)	DCP (g)	TDN (kg)	DCP (g)	TDN (kg)	ME (Mcal)
250	-	-	-	168	2.02	7.27	140	2.2	168	2.02	7.27
300	-	-	-	197	2.36	8.50	168	2.65	197	2.36	8.50
350	-	-	-	227	2.70	9.72	195	3.10	227	2.70	9.72
400	318	3.13	12.01	254	3.03	10.91	223	3.55	254	3.03	10.91
500	364	3.70	14.20	296	3.69	13.28	278	4.45	296	3.69	13.28
550	386	3.97	15.25	336	3.71	13.36	310	4.90	336	3.71	13.36

sesame, etc.), chunnies (broken pulses with hulls) or brans (wheat or rice). Some farmers in the milk shed areas recently adopt the use of balanced concentrate mixes for feeding to their dairy cattle. However, many continue on the traditional methods and they do not know the scientific nutrient requirements such as developed by NRC, ARC or ICAR. Their animals are hardly ever fed according to the nutrient requirements for maximum biological production of a single commodity, neither in India, nor in many other countries of Asia, or even the so-called developed world. That is to say, farmers do not use book values and terms like TDN or CP, but they implicitly use standards as they have learned by experience (Rangnekar, 1993; Jackson, 1981; Schiere and de Wit, 1993). The village animals in low input systems rely on local feeds of which the availability differs between regions. Farmers are sometimes forced to accept low productions of their animals for economic reasons, due to non availabitity of good forage crops and concentrates. In the forseeable future it is not possible to feed a large part of Indian cattle as per nutrient requirements, if these requirements are conceived as fixed amounts of nutrients that need to be supplied for maximum biological production. Standards or requirements can however be useful if they are conceived as a set of rules, based on farm and laboratory experience, to be used for the design of economically feasible feeding systems. Too often the scientists and policy makers assume production objectives that are not the same as those of the farmers. In that sense it is the application of feeding standards rather than their principle that needs reconsideration.

The majority of non-descript cows yield an average 1-2 litres of milk per day and such animals need little or no concentrates when the basal roughage is of reasonable quality and quantity. The medium producing cows yielding 8-10 litres of milk, require better feeds depending on their body weight, i.e. relative requirements for maintenance feed. Such feed is not always available at economically attractive prices. The proper use of standards can help to determine the most economic/attractive level of production. Straw and some green feed with salt and mineral mix should be sufficient for animals on maintenance, or for animals that need to survive a dry season. Similarly, work animals should be given some extra feed for normal work, and for hard work more concentrate feeds need to be fed.

CONCLUSIONS

There is no large difference in the feeding requirements for large ruminants between NRC, ARC, Sen *et al.* (1978) and ICAR (1985) for both maintenance and production. However, village animals in India and many other Asian countries are hardly ever fed according to theoretical nutrient requirements for high individual productions. Farmers objectives of livestock production are often misinterpreted, animal survival can be of

Table 5. Nutrient requirement for milk production (nutrients/kg of milk)

Butter fat (%)	NRC (1989)			Sen et al. (1978)			ICAR (1988)	
	CP (g)	TDN (g)	ME (Mcal)	DCP (g)	TDN (g)	ME (Mcal)	DCP (g)	TDN (Mcal)
3.0	78	280	1.07	40	269	0.97	48	275
3.5	84	301	1.15	-	-	-	51	300
4.0	90	322	1.24	45	316	1.14	55	325
4.5	96	343	1.32	-	-	-	58	350
5.0	101	364	1.40	51	363	1.31	62	375
5.5	107	385	1.48	-	-	-	65	400
6.0	-	-	-	57	411	1.48	68	425
7.0	-	-	-	63	458	1.65	75	475
8.0	-	-	-	69	439	1.82	79	500
9.0	-	-	-	75	553	1.99	-	-
10.0	-	-	-	81	602	2.17	-	-
11.0	-	-	-	85	650	2.34	-	-

Table 6. Nutrient requirement for work production in cattle

Live weight (kg)	Sen et al. (1978) and Ranjhan (1990)						Kearl (1982)					
	Normal work (4h)			Heavy work (8h)			Normal work (4h)			Heavy work (8h)		
	DCP (g)	TDN (kg)	ME (Mcal)	DCP (kg)	TDN (kg)	ME (Mcal)	DCP (kg)	TDN (kg)	ME (Mcal)	DCP (kg)	TDN (kg)	ME (Mcal)
200	0.24	2.0	7.2	0.25	2.7	9.7	-	-	-	-	-	-
300	0.33	3.1	11.2	0.42	4.0	14.4	0.227	3.1	11.1	0.241	3.9	14.1
400	0.45	4.0	14.4	0.57	4.8	17.3	0.283	4.0	14.4	0.287	5.0	18.2
500	0.56	4.9	17.6	0.71	6.4	23.0	0.332	4.8	17.3	0.362	6.1	22.1
600	0.66	5.8	20.9	0.84	7.2	25.1	0.370	5.6	20.1	0.418	7.1	25.8

Note:
- There are no requirement by NRC, ARC and ICAR for work production in cattle

prime importance in situations of severe feed shortage. High production of a single commodity, for example milk, is not always economically attractive to the farmers. Socalled scientific standards are often developed in conditions and with objectives that differ considerably from practical farmin, i.e. they differ from the feeding standards that are developed indigenously by farmers in their own system. For many farmers there is no possibility to use the nutrient requirements for feeding of (large) ruminants at high productions. Only farmers in highly commercialized systems with high producing dairy animals are capable to buy feeds/concentrates at large scale. Feeding trials and recommendations for village farmers should be with rations based on locally available feeds (i.e. crop residues) and based on farmers' objectives.

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MODERN APPROACHES TO FEED EVALUATION AND THEIR APPLICATION IN INDIA

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SUMMARY

In order to predict animal response to given feeds or their combinations it is required to assess the nutritional value of feeds. This can be done by a whole range of animal trials and laboratory measurements. The most relevant methods are explained in this paper, relating international developments with Indian work. Besides the traditional methods of feed evaluation, attention is given to recent approaches such as fibre fractionation, in vitro, in sacco/situ *and gas production methods. Finally, some attention is paid to issues of dry matter intake and the relation between these feed parameters and actual animal performance.*

INTRODUCTION

Data on the nutritional quality of feeds and forages are needed to predict the response of animals to different feeds and combinations of feeds. In some situations this will lead to the purchase of additional feeds to meet preset production targets; in situations where purchase is not possible, standards enable better use to be made of available feed resources (Schiere and De Wit, 1993). The best 'predictors' are the results of animal production trials, but these are expensive to conduct and the results are dependent on other management factors. Scientists have therefore developed alternative techniques which are cheaper by using smaller amounts of feed. The majority of these measure chemical composition in the laboratory, but for ruminants, such methods are often inadequate to predict the availability of the chemical components to the rumen microbes. Hence, *in vitro* and *in sacco* (also called *in situ*) methods for measuring the response to feeds in terms of fermentation by rumen microbes, have been developed. The results of all these methods can be used either as inputs to feed rationing models, or simply to rank feeds, a process which is also undertaken by farmers, based on field observations. This paper reviews past and present feed evaluation systems with special reference to their application for development of ruminant production in India.

THE PROXIMATE ANALYSIS

One of the earliest and still most widely accepted methods of reporting the chemical composition of feeds and fodders is the proximate analysis. It was developed by Henneberg and Stohmann

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in the last century (Van der Honing and Alderman, 1988). The method is also called 'Weende analysis' because it was developed in a German town called Weende. In this method, the feed is analysed for water, crude protein, crude fibre and ash, whereas the remaining dry matter is referred to as nitrogen-free extract, a fraction that mainly represents non-structural carbohydrates. This method was universally accepted and is still followed in many countries including India. Most of the research publications of ICAR (Ray and Ranjhan, 1978; Ranjhan, 1993) and manuals/ reports from various animal nutrition research laboratories publish their data on chemical composition in proximate analysis of green fodders, grasses, hays, straws, oilseeds and cakes, by-products of pulses and cereals and agro-industrial by-products, most of which have been compiled and published by ICAR (Ranjhan, 1993).

The proximate analysis partitions the dry matter into five fractions, but the partitioning of the carbohydrate fraction in particular, is not consistent with the chemical components. The crude fibre method does not reliably recover all of the lignin, cellulose and hemicellulose and thus the ratio between crude fibre and NFE is variable. Further, since NFE is calculated by difference, analytical errors, or assumptions such as the calculation of crude protein as 6.25 times total-N, can cause marked errors in the proportion of dry matter attributed to this fraction. Moreover, the value of a feed to ruminants is particularly dependent on the digestibility of the carbohydrate fraction, which affects the amount of energy which reaches the animal's tissues. This digestibility in turn is dependent on the ratio of structural (cell wall) to non-structural carbohydrates and thus any system to predict the nutritive value of feeds for ruminants must make an accurate partition between these fractions. Thus, the initial efforts in developing new methods concentrated on improved procedures for carbohydrate, in particular cell wall, analysis. This is particularly important in India, where many of the feeds have high cell wall contents and hence many of the new methods for cell wall analysis have been adopted here.

NEW APPROACHES

Van Soest fibre fractionation

Various schemes for partitioning of total carbohydrates have been proposed (Crampton and Maynard, 1938; Crampton and Whiting, 1943) but none was so widely accepted as the scheme proposed by Goering and van Soest (1970). Their detergent system of feed analysis fractionates the feed into cell contents (Neutral Detergent Solubles, NDS, which are soluble at pH=7) and cell walls (Neutral Detergent Fibre, NDF). The cell walls are further fractionated into hemicellulose, cellulose and lignin by dissolving them at different pH levels. The fractionation process is presented in Figure 1.

Figure 1. The process of fibre fractionation according to the Van Soest detergent analysis.

Step			Abbreviation
	Feed dry matter		
1		extracted with neutral detergent (pH 7) Cell contents dissolve (neutral detergent solubles)	NDS
	Cell walls remain	neutral detergent residue also called neutral detergent fibre	NDR NDF
2		extract with acid detergent (pH 0) Hemi cellulose dissolves (=acid detergent soluble)	ADS
	Acid detergent fibre remains		ADF
3		digest with permanganate solution Cellulose dissolves	
	Lignin and ash remains		
4		ashing Lignin disappears	ADL
	Ash remains		

The advantage of the detergent system of fibre analysis is that it partitions carbohydrates according to nutritional criteria. The NDS fraction is almost completely digestible, while the fibre fractionation gives estimates of the cellulose, hemicellulose and lignin contents. However, even this information is not adequate for accurate prediction of digestibility. Clancy and Wilson (1966) developed a modified acid-detergent fibre (MADF) method which did appear to relate more closely to digestibility. Their method has been used in the UK extension service to predict digestibility, but prediction based on *in vitro* digestibility or neutral detergent cellulase (Dowman and Collins, 1982) appears to be better for a range of forages (Barber *et al.*, 1984).

Crude protein

While the emphasis was initially directed towards improved carbohydrate analysis, the estimation of crude protein as 6.25 times total-nitrogen, assuming proteins contain an average of 16% nitrogen, was accepted as sufficient definition. However, particularly when feeding for high production, further refinements are required. In the UK digestible crude protein was replaced by rumen degradable (RDP) and undegradable protein (UDP) in the ARC feed rationing system published as ARC (1980). This system and its relevance is discussed in detail by Sampath *et al.* (1993) and by Walli *et al.* (1993) in these proceedings and hence will not be considered further here. Many data are now available on the RDP and UDP contents of Indian feeds and fodders, and have been published in Indian scientific journals.

FERMENTATION METHODS

In vitro digestibility

Digestibility is a measure of the efficiency with which the animal can extract nutrients from a particular feed. It is measured *in vivo*, by total collection, i.e. where a daily record of feed intake and faecal output is kept over a 7-10 day period (Schneider and Flatt, 1975). However, this is not only an expensive procedure, but also laborious and time-consuming. Digestibility can be predicted from fibre analyses as referred to above, but more accurate predictions involve the incubation of feed *in vitro*, either with rumen microbes or with plant cellulases.

The traditional *in vitro* method was first described by Tilley and Terry (1963) and the principle of their approach was to incubate a feed sample with rumen liquor and a buffer under constant temperature for 48 hours, followed by 48 hours of digestion with pepsin in weak acid (about pH=2). The residue is then ashed and a value for organic matter digestibility can be determined. The full procedure is time-consuming and modifications including deletion of the HCl pepsin phase and the use of synthetic (hemi)cellulases to replace the need for rumen innoculum have been developed. These methods are quicker and cheaper, but not usually as accurate.

In situ degradability

All the *in vitro* methods discussed so far are end-point methods, i.e. they estimate digestibility from a fixed period of incubation. Correlations between *in vivo* and *in vitro* data are better with shorter (than 48h) incubation periods, but the 'best' incubation time is dependent on plant species and hence a time in excess of that thought to be required for maximum digestion was selected. An alternative approach is to look for a method which enables the rate of digestion to be measured. A much more popular method is the use of the *in situ*/*in sacco* or nylon bag method which is now being practiced by Indian scientists.

The use of bags for the incubation of feeds within the rumen to determine degradability was first suggested by Quin *et al*. (1938) and standard procedures were recommended by Ørskov *et al*. (1980). A small amount of feed material is weighed into a number of dacron or nylon bags, which are incubated in the rumen of fistulated ruminants, for varying periods of time. The curve representing the disappearance of material from the bag is analysed by an equation (Ørskov and McDonald, 1979; Orskov, 1987) which gives parameters for the soluble fraction, the potentially degradable, but insoluble fraction and the rate of digestion. Analysis of the residue can enable these parameters to be determined for dry matter, organic matter, fibre fractions of protein and estimation of the retention time of the feed in the rumen enables calculation of an effective degradability (Ørskov and McDonald, 1979). However, effective degradability should only be calculated where retention times have been measured on the same feed, since they will vary markedly between diets.

There is evidence (Ørskov *et al.*, 1989) that there can be good correlations between the 3 parameters referred to above and voluntary intake, but there can also be extreme variability between labs in the repeatability of the method.

Gas production methods

Measurement of the rate at which gas is produced during *in vitro* fermentation in the laboratory is another alternative for deriving an estimate of the rate of degradation of feeds. This method was first described by Menke and Ehrensvard in 1974 and further refined by the same group (Menke *et al.*, 1979). This method relies on an inverse correlation between net gas accumulation and the rate and extent of digestion of the feedstuff. The fermentation is conducted in large (100ml capacity) ground-glass syringe barrels, which contains the feedstuff in an anaerobic medium inoculated with rumen fluid. Gas production can be read from the movement of the plunger in the syringe. Adoption of this method appeared to be much slower than for the dacron bag, possibly due to the expense of the syringes. More recently, a method developed by Theodorou *et al* (1992) in the UK (unpublished as yet!) uses a simple and cheap pressure transducer to determine the gas production profiles of feeds. Work by Indian scientists using gas production is reported by Manget Ram and Gupta (1990) and by Wood, Sampath and Prasad (pers.comm. 1992).

Many research centres in India (amongst others: Indian Veterinary Research Institute, National Dairy Research Institute, Haryana Agricultural University, Punjab Agricultural University, Indian Grassland and Forage Research Institute) have adopted *in vitro* fermentation techniques and many have been in use over a long period of time. These techniques are particularly useful in the screening of large number of forage samples, for example as part of plant breeding programs and management experiments as reported in session five of these proceedings. These methods are also useful for the investigation of associative effects, where the utilization of one feed in the rumen is affected by the presence of another feed (Prasad *et al.*, 1992; Sampath *et al.*, 1992).

DRY MATTER INTAKE

The value of a feed to an animal is only realised if the animal is prepared to consume it. Thus any method of feed evaluation should include an estimate of voluntary intake. However, intake is dependent not only on the composition of the feed, but also on attributes of the animal, such as liveweight and physiological state, management practices, such as ease of access to feed and environmental conditions. Some of these act independently of plant characteristics and intakes of feeds will still rank in the same order, but others will interact with the quality of the feed.

Many attempts have been made to predict feed intake from laboratory and other measures (Mertens and Van Soest, 1973; ARC, 1980; Mertens, 1985; Forbes, 1986; NRC, 1987; Ørskov *et al.*, 1989; Ketelaars and Tolkamp, 1992) but most equations are only accurate within a limited range of feeds. For the purposes of feed evaluation, a ranking system is probably sufficient and one method worthy of further consideration is the short-term intake method proposed by Kenney and Black (1984). In this method animals are starved for short periods, prior to being offered a small amount of feed and intake measured over periods of up to 30 minutes. The advantage of the method is that only small amounts of feed are required, while still allowing the animal to express its preference, but the disadvantages are the extreme variability between animals and the fact that the correlation between short-term and long-term intake again may interact with feed quality. Further analysis of *in situ* degradability and gas production data may also be useful. For example Van Soest (1982) suggested that the highest correlation between *in vitro* digestibility values and voluntary intake values occurred at 6 to 12 hours of incubation.

When intake is measured, it is also imperative to consider the effect of selective consumption. By offering the animals varying levels of excess feed, they are capable of selecting the better parts of the feed. In this way both the quality and the quantity of the feed consumed is variable (Zemmelink, 1980; Prabhu et *al.*, 1988; Wahed, 1990; Schiere *et al.* 1990).

RELATING FEED VALUE TO ANIMAL RESPONSE

In order to predict the response of animals to a particular feed, the value needs to be related to the animal's ability to convert the feed into meat or milk. Systems which relate these two aspects are discussed in detail by Ranjhan and Kiran Singh (1993) and only the problems of integrating the chemical composition of feeds into quantitative indices in the same units as animal requirements are considered here.

The proximate system of analysis led to the development of the Total Digestible Nutrients (TDN) system. In this system, values were assigned to the TDN required for maintenance and per kg liveweight gain or per litre milk production and these could be related to the amount of TDN supplied by individual feeds. However, this system requires assumptions to be made as to the digestibility of the individual nutrients, in addition to the problems already discussed concerning the inaccuracies of proximate analysis. Equations to predict TDN from individual components have been derived outside India but such equations are derived empirically and therefore are unlikely to be accurate for Indian feeds.

The TDN system has been replaced in many countries by systems which use energy as the common currency to relate feed quality to animal requirements. The gross energy of the feed can be measured by bomb calorimetry in the laboratory, but not all of this energy is available to the animal. Some is lost in faeces, urine, methane and heat, leaving net energy available to the animal (see Fig 2). However, net (NE), or even metabolisable energy (ME), is difficult to measure, requiring the use of respiration calorimeters to measure the exchange of gases (O_2, CO_2, and CH_4) between an animal and the environment. Such calorimeters are available in India at IVRI, but they are unable to generate data on all the feeds and mixtures of feeds offered to the wide range of ruminant species and breeds in India. Thus many scientists still rely on the values for ME content of feeds provided in the UK system (ARC, 1980).

Figure 2 Partition of energy

GROSS ENERGY

→ Faecal energy

DIGESTIBLE ENERGY

→ Urine energy +

→ Methane energy

METABOLISABLE ENERGY

→ Heat

NET ENERGY

In some cases the use of ARC or NRC tables provides useful approximations, but it should be remembered that the tables were developed from data obtained from experiments with high-producing cows, offered high quality rations to maximize production. The Indian situation is very different. First of all the objectives of the farmer need to be considered: does he or she wish to maximize production per animal or to maximize utilisation of available resources? If the latter is true, then data on feed composition should be used to ensure that the animals are offered a diet which is balanced, as far as possible, in terms of energy:protein ratio and, for higher levels of production. One of the problems in achieving this is that the balance of energy:protein required by Indian ruminants may be different from that of European breeds.

Thus, there is a need for more experiments to be conducted with local animals. It will only be possible to extrapolate from the results of such experiments to practical situations, where the animals, the feeds offered and the management systems within which the measurements have been made, are described in sufficient detail. Ideally feeds should be offered at different levels to enable response curves to be drawn, to assess the effect of selective consumption and to allow for interactions between level of feed offered and animal potential. Comparison of these results with estimates derived from the ARC system and the new systems emerging from the U.S.A. should then enable recommendations with more specific application to Indian farmers to be made.

CONCLUSIONS

There are various methods available for feed evaluation namely the proximate analysis, the detergent system of feed analysis, the method distinguishing rumen degradable protein (RDP) and undegradable protein (UDP), the *in vitro* feed digestion, *in situ* degradation, the gas production method and the measurement of dry matter intake. However, the ultimate test of feed evaluation is the overall animal response to a particular feed or a combination of feeds in terms of milk, growth, body condition and health, reproduction, health and other locally important features. The Indian Tables giving the chemical composition and energy values could be integrated into quantitative indices for maintenance, growth and milk production. Most Indian farmers do not understand the nutrient requirements as expressed in the Tables. More experiments are needed to determine overall animal response to different feed combinations, utilizing data on chemical composition of the locally available feeds.

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NUTRITIVE VALUE OF STRAW

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SUMMARY

The energy content of a feed can be described as gross energy (GE), digestible energy (DE), metabolisable energy (ME) or net energy (NE) for maintenance (NE_m), growth (NE_g) or lactation (NE_l). This paper describes straw in respect of the various energy fractions and the factors responsible for the low energy availability from straws.

INTRODUCTION

Straws and stovers are potential energy feeds because of their high cellulose and hemicellulose contents. Unfortunately the energy in the cellulose and hemicellulose is only partly available to animals, because of poor digesti-bility due to inhibitory elements in the straws. The energy value can be expressed in different ways as shown in Table 1, which gives a schematic representation of the various energy measurement and how they are related to nutritional factors.

Feed evaluation systems to assess the energy value of a feed can be based on DE (TDN system), ME (ARC, 1980) or sometimes NE (NRC, 1984). Energy is digested in the rumen, in the small intestine (energy containing proteins) and in the large intestine and absorbed from the gastro-intestinal tract. However, a part of the energy not recovered in faeces will not be available at tissue level due to losses as methane and in urine. Energy available at tissue level can only partly be used for metabolism. Energy losses are inevitable and determined by digestive and metabolic processes. In this paper various factors will be presented that are responsible for the low nutritive quality of straws.

Gross energy

The gross energy (GE) of carbohydrates (CH_2O) is 4.3 Kcal/g, of protein 5.6 Kcal/g and of fat is 9.2 Kcal/g. Since straws do not vary much with regard to fat and protein contents, the average GE is almost similar for all straws (see Table 2). Rye grass has a slightly higher GE content on DM basis than straws. But the DE, ME, NE_m and NE_g values are much higher in grass than in straws, because of factors that reduce the availability of energy from straw for the animal.

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Digestible energy

A classification of roughages as proposed by Ellis *et al.* (1988) is given in Table 3. The OMD of straws, which is highly related to the energy digestibility, is generally varying from 40 to 55% (Mangat Ram, 1989; Singh and Gupta, 1990; Mohini and Gupta, 1990) and should be classified as low.

The NDF and lignin contents for wheat and paddy straw is shown in Table 4. Both straws should be classified as low quality roughages based on their NDF content.

On the whole, NDF, lignin and silica content of straw are negatively correlated with digestibility (see Table 5). Between and within straws there is however a considerable variation in the effect of lignin on digestibility. For straw from 22 rice varieties grown in Sri Lanka no significant correlation was observed between *in vitro* cell-wall digestibility and lignin content of cell walls (Oosting, unpublished results).

Table 1 Energy definitions in relation to nutritional factors.

Energy definition	Abbreviation	Nutritional factors
1. Gross Energy	GE	Feed composition: - fat (9.2 Kcal/g) - protein (5.6 Kcal/g) - carbohydrates (4.3 Kcal/g)
2. Digestible Energy GE - faecal energy	DE	Feed composition: - cellwall concentration and - composition - nitrogen concentration Metabolic faecal energy losses Intake level
3. Metabolizable energy DE - urinary energy - feecal energy	ME	Excretion of energy urine Production of methanogenic volatile fatty acids in the rumen
4. Net energy ME - heat losses; NE_m = net energy for maintenance NE_g = net energy for growth	NE	Utilization of absorbed nutrients Heat losses due to chewing, rumination and digestion - increased heat losses with increased ME intake or lower quality of feed. NE_m higher than NE_g

Table 2 Energy contents of straws (Mcal/kg DM).

Straws/ grasses	GE (Mcal/mg DM)	DE	ME	NE_m	NE_g
Wheat straw	4.3	1.8	1.48	0.64	0.11
Rice straw	4.0	1.8	1.48	0.65	0.09
Barley straw	3.9	1.8	1.45	0.60	0.08
Bermuda straw	4.4	2.7	2.17	1.31	0.74
Rye grass	4.6	3.0	2.46	1.57	0.97

Source: NRC (1984).

Table 3 Gradation of roughages based on nutritional characteristics.

Type	NDF (%) in OM	Lignin (%) in NDF	OMD (%)	DMI
High	<45	<5	70	90
Medium	45-65	5-10	55-70	70-90
Low	65-80	10-15	45-55	50-70
Poor	80	15	<45	<45

Source: Ellis et al. (1988).

Table 4 Fibre and lignin content in crop residues.

	NDF	ADF	Lignin	Reference
Wheat straw	75.23	50.84	9.60	Walli et al. (1987)
	79.43	58.43	11.90	Kundu and Mudgal (1985)
	82.06	63.94	12.27	Singh and Gupta (1990)
	78.13	55.33	15.00	Franzidas and Porteous (1981)
Paddy straw	64.97	49.03	9.17	Yadav and Yadav (1988)
	79.74	59.27	5.79	Rao et al. (1987)
	66.24	50.83	10.00	Franzidas and Porteous (1981)

Table 5 Correlation coefficients between in IVDMD and some components of feeds.

X_1	X_2	$r(X_1, X_2)$
IVDMD	NDF	-0.44^*
	Lignin	-0.71^{**}
	Silica	-0.48^*
	OMD	$+0.79^{**}$

Source: Roxas et al. (1984)
* $P < 0.05$; ** $P < 0.01$

Table 6 CP contents in straw and ammonia N concentration inrumen fluid

Straw	CP (%) (N*6.25)	Ammonia (mg/l)	Reference
Wheat straw	3.86	63	Verdonk et al. (1989)
	4.36	46	Mangat Ram (1989)
	3.98	49	Singh and Gupta (1990)
	3.48	39	Srinivas (1991)
Paddy straw	2.5-9.37	-	Doyle et al. (1986)
	5.69	-	Yadav and Yadav (1989)
	4.56	-	Mohini and Gupta (1990)
	6.86	88	Sharif (1984)

The relation between DE and availability of straw nitrogen and minerals

Cereal straws are a poor source of CP (see Table 6), due to a low concentration and a low availability of CP for rumen microbes. The degradability of cell wall associated N in rice straws after 48 hours of incubation in rumen fluid was 48.5% (Oosting, unpublished data). Rumen N availability from straws for microbial digestion may be limited as shown by Oosting *et al.* (1989), although *in vivo* supplementation of straws with a N source does not always result in an increased rumen digestibility (Ørskov and Grubb, 1978).

Metabolizable energy

The ME content of straws is low as compared with most grasses. ARC (1980) stated that 20% of DE is lost as energy in urine and methane independent of the quality of the feed. Total losses of DE in methane and urinary energy of rations based on wheat straw and ammoniated wheat straw fed to cattle and sheep were 18-29% (Oosting *et al.*, unpublished). This indicates, that straws do not differ from other feeds with regard to total losses in methane and urinary energy.

However, during the fermentation of straws, the proportion of acetate is higher and the proportion of propionate lower than in grasses (see Table 7). The methanogenic volatile fatty acids (acetate and butyrate), of wheat and paddy straw diet varies from 80-88% whereas it is about 70% in case of grass. Thus energy losses in the form of methane could be theoretically higher in straws than in better quality feeds.

Net energy

The efficiency of utilization of ME for NE (expressed as k value) decreases with the feed quality. The k value for maintenance does not differ much between feeds (ARC, 1980). Above maintenance higher efficiencies can be expected for better quality feeds than for lower.

Low quality feeds require more grinding energy than better quality feeds as shown in Table 8 (Doyle, 1983). He reported that grinding energy was much higher for untreated wheat straw than for the same straw treated with 5% sodium hydroxide. The higher heat loss observed with low quality feeds in comparison to better feeds could probably partly be explained by an extra heat production associated with chewing and mastication.

Dry matter intake (DMI)

The dry matter intake of an animal is an important parameter in determination of the energy intake. DMI is low when animals are fed straw alone as further elaborated by Prasad *et al.* (1993 a,b) (see Table 9). Comparison of the intake data in Table 9 with the classification of roughages as given in Table 3 shows that straws should be classified as poor/low, with regard to intake.

Table 7 Total Volatile Fatty Acids (VFA), molar percentage and methanogenic percentage of VFA on straw diets.

Straw	VFA molar proportion (%)			
	Acetate	Propionate	Butyrate	Methanogenic
Paddy straw[1]	79.0	15.4	4.2	84.4
Wheat straw[2]	71.0	16.0	13.0	84.0
Grasses	60.0	30.0	10.0	70.0

[1] Sharif (1984); [2] Srinivas (1991).

Table 8 Dry matter intake and grinding energy required for milling of rice straw

Straws	DMI (g/kg$^{0.75}$/day	Power consumption (J/g DM)
Rice straw untreated	28-38	150
Rice straw treated with 5% NaOH	64	74
Rice straw soaked in 5% NaOH	71	89

Source: Doyle (1983)

Table 9 Dry matter intake when fed straws.

Straw	Intake		Reference
	kg/100 kg	BWg/W$^{0.75}$/kg	
Wheat straw	1.27	48.77	Mangat Ram (1989)
Wheat straw	1.40	55.51	Singh and Gupta (1990)
Wheat straw	-	43.00	Thiago et al. (1979)
Oat	-	51.00	Thiago et al. (1979)
Paddy straw	1.61	64.13	Mohini and Gupta (1990)

Source : Prasad et al, 1993a,b

CONCLUSIONS

Straws form a potential source of feed energy, particularly for ruminants. But many factors cause energy in straws to not be as available as in grasses. The energy in straws and grasses can be expressed in different ways, i.e. Gross -, Digestible -, Metabolizable - and Net Energy.

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METHODS TO ASSESS THE PROTEIN VALUE OF FEEDS FOR RUMINANTS

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SUMMARY

The traditional measurement of digestible crude protein (DCP) does not represent the actual protein absorbed from the feed in ruminants. New protein evaluation systems are based on the quantity of protein available for absorption from UDP and microbial protein. The quantity of UDP available from different feedstuffs and its digestibility in the small intestine can be estimated by in vivo, in situ *and* in vitro *techniques. The microbial protein synthesised in the rumen is estimated* in vivo *using markers or on the basis of OM digested in the rumen, and its intestinal digestibility is estimated either by* in vivo *or* in vitro *techniques. The advantages and limitations of different techniques are discussed. Feed materials of animal origin and heat processed feed materials usually provide high UDP. The intestinal digestibility of UDP is generally higher in concentrates than in roughages.*

INTRODUCTION

The nutritional value of a dietary protein depends on the quantity and quality of amino acids which it provides for absorption from the small intestine in the animal's body. In ruminants, the need to consider separately the N requirement for rumen microbes and amino acid requirement for the host animal has led to the development of new protein evaluation systems.This paper explains new aproaches to assess protein value of feeds for ruminants. The relevance of these systems is discussed by Walli *et al.* (1993).

DIGESTIBLE CRUDE PROTEIN (DCP) SYSTEM AND ITS LIMITATION

The difference between the N-input in the feed and N-excretion in faeces gives a good estimate of net N-absorption by the body. However, in ruminants part of this absorption take place from the rumen in the form of ammonia which after conversion to urea in the liver, is partly excreted in the urine and partly recycled back to the rumen via saliva. Also, Through proteolysis followed by protein systhesis by rumen bacteria, the amino acid composition of the feed protein is greatly altered in the rumen. Furthermore, a part of the absorbed feed protein is replaced by a variable amount of endogenous protein, which has been synthesised at a higher energy cost to the animal. Therefore,

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apparent digestible crude protein (DCP) is no good indicator of amino acid absorption. Another limitation for the use of DCP is the difficulty to accurately measure N-balances. Moreover, apparent protein digestibility can also be predicted from the level of crude protein in the feed DM (Minson, 1982). The simplified equation is DCP = 0.9 * CP - 32, where (D)CP is in g/kg DM. This general relationship leads to the allocation of negative values for low protein diets, which is explained by the MFN excretion that exceeds dietary intake in low protein diets. This equation is based on a true protein digestibility of 90%, represented by the regression coefficient of .9, which is high for straws. Further, this equation suggests a loss of 32 g of protein per kg of ingested DM. These losses result from endogenous secretions or from microbial synthesis in large intestine. When the latter results from incorporation of urea after an influx of urea from the blood, this is not a real loss, because the urea would otherwise have been lost in the urine. If microbial synthesis results from conversion of endogenous protein, the real loss is larger, because considerably more amino acids are needed to replace the ones lost in endogenous losses.

The digestibility of nitrogen can be depressed due to heat, applied during processing or generated during storage of feeds, especially forages (Thomas *et al.*, 1982). The indigestible dietary nitrogen is correlated with N present in ADF (Van Soest, 1982). Also dietary manipulations which result in a shift in the site of fermentation of carbohydrates from rumen to caecum and colon lead to the capture of N by the microbes in the large intestine and its subsequent excretion in the faeces (Ørskov, 1982). This would give lower DCP values.

NEW APPROACHES

In order to overcome the limitations of the DCP system, current research efforts are designed to develop procedures to determine the quantitative and qualitative flow of amino acids from the rumen to the abomasum and small intestine. When these goals are achieved, and coupled with good amino acid requirement data, the balancing of rations for ruminants can be approached in a manner similar to those of monogastric animals. The relevance of these systems for ruminants is discussed by Walli *et al.* (1993)

Two major sources of protein from which amino acids are available for absorption in small intestine, are undegraded dietary protein (UDP), and microbial protein synthesised in the rumen.
Based on the availability of protein from these two sources in the small intestine, several new systems for expressing the protein requirement of ruminants have been proposed and are reviewed by Honing and Alderman (1988). These include:

- the RDP - UDP system of Great Britain, (ARC, 1980; 1984),
- protein digested in intestine (PDI) system of France (INRA, 1987),
- absorbable protein system of Switzerland (Landis, 1984),

- crude protein flow system of Germany (Rohr *et al.*, 1986),
- absorbed protein system of United States (NRC, 1985),
- the Scandinavian AAT-PBV system (Nordic Kontaktorgein for Jordbruksforskning, 1985).

The underlying principles of all these systems are similar. They all predict the total amino acids absorbed from the small intestine, and they consider separately the N requirements of rumen micro-organisms and the amino acid requirement of the host animal. If the diet fails to meet the N requirement of the rumen micro-organisms, NPN substances can be used as N supplements. If the protein requirement of the host animal is greater than that contributed through rumen microbial protein, then the diets need to be supplemented with slowly degradable protein sources (Walli *et al.*, 1993). However effective ration formulation using the new ruminant protein feeding systems depends on the accurracy of estimation of UDP and microbial N supply to, and digestion in, the small intestine.

ESTIMATION OF UDP

The UDP content of feeds can be determined either by the *in vivo* or the *in vitro* method or by estimating protein degradability in the rumen *in situ*.

In vivo method

In vivo methods estimate the UDP from the post ruminal sampling of abomasal or duodenal contents. The relatively long time and large amount of feed required restrict the use of *in vivo* procedures for routine determinations of degradability of large number of feed samples. Besides, estimation of UDP by *in vivo* techique is an indirect method, in which UDP is determined as the difference between total intestinal protein flow and sum of the microbial protein flow (estimated with markers) and endogenous protein flow, estimated using the equation (Hogan and Weston, 1970). Inaccurate differentiation between protein of feed and microbial origin due to variability in microbial and particle marker technique (Santos *et al.*, 1984) leads to errors. *In vivo* estimates are also subject to errors from assumptions regarding the amount of endogenous N entering the small intestine (Egan *et al.*, 1984). Representative sampling of both solid and liquid phases is essential but difficult. Improper sampling leads to errors.

In situ techniques

The *in situ* or nylon bag technique involves the incubation of feeds in the rumen in synthetic fibre bags for several time periods in the rumen. Disappearance versus time of incubation is interpreted to calculate the rate constant for degradation, which can be combined with an estimate of fractional outflow rate of protein from the rumen to predict effective protein degradability

(Ørskov and McDonald, 1979; Mathers and Millers, 1981; McDonald, 1981). An inherent weakness of this procedure is the assumption of a constant flow rate, since UDP values are affected by this rate of flow. Although this technique is conducted in a rumen environment, many inherent factors, such as bag porosity, ratio of sample size to bag surface area, microbial contamination, diet of the animals, incubation procedures, washing etc., influence the estimate of protein degradation. These have been reviewed by Lindberg (1985) and Nocek (1988) and standardized procedures have been suggested to obtain reproducible results. Estimations of protein degradability of reference samples simultaneously with the test samples helps to minimize variations in the values obtained from different laboratories. However, the reference samples are to be developed in any of laboratories, for these purposes. Another problem associated with the nylon bag technique is the loss of a fraction of protein from the bag due to small particle size and washing. This fraction is generally assumed to contain that part of the protein which is highly soluble and hence completely degradable in the rumen. However the results of some studies (Mahadevan *et al.*, 1980) indicate that soluble true proteins in some feedstuffs are not likely to be completely degradable. Therefore, it is sometimes erroneous to assume that all soluble proteins are degraded in the rumen. From the laboratory point of view, the *in situ* technique is simple and can use lactating cows with rumen fistulae which consume feed at rates comparable to those in commercial situations. However, this technique requires the use of fistulated animals.

The CP content of poor quality roughages is generally low. Therefore the determination of protein degradability of these feeds by *in situ* technique requires correction for microbial contamination of feed residues left in the bag after incubation in the rumen. The percent error associated with protein degradability values of roughages not corrected for microbial contamination may be very high as was reviewed by Nocek (1988). However, the method to determine microbial contamination is very tedious. Development of equations to predict the extent of microbial N contamination for different categories of feeds may help in minimizing this problem.

In vitro method

The *in vitro* method of determining protein degradability involves the use of either rumen inocula or proteolytic enzymes. The procedures involving rumen inoculum are usually based on the rate of ammonia accumulation on incubating the feed protein in rumen fluid. The varying rate of reutilization of ammonia for microbial synthesis which depends on the rate and extent of fermentation of available substrates particularly carbohydrates in the incubation medium is the limiting factor in this method. Problems associated with *in vitro* methods have been reviewed by Broderick (1982), who has further improved the technique to include chloramphenicol with hydrazine sulphate which inhibits microbial metabolism of amino acids and ammonia (Broderick, 1987). The gas production technique which was designed to estimate OM degradability is further modified (Raab *et al.*, 1983) to estimate protein degradability. Estimates of protein degradability and microbial protein synthesis are obtained from the relationship between the fermentation of carbohydrate (measured by gas production) and the disappearance of ammonia N from the incubation medium. The dual flow continuous culture system (eg. Rusitech) incorporates a dual effluent removal system designed to simulate the differential flow for both liquids and solids (Hannah *et al.*, 1986; Garett *et al.*, 1987). This system allows for a rapid buffer input for maintenance of pH which permits longer residence time for digestion of particulate matter. However, these methods are limited to laboratories with automated equipments.

A different approach in *in vitro* methods is the use of various proteolytic enzymes to estimate ruminal protein degradability. Commercially available proteases have been tested for this purpose (Krishnamoorthy *et al.*, 1983; Poos Floyd *et al.*, 1985). Mahadevan *et al.* (1987) pointed out that the use of proteases from sources other than rumen microbes may not have the same action on feed protein as rumen proteases. But the extraction of protease from rumen microbes is very tedious. However, the methods involving proteolytic enzymes are very simple and do not require fistulated animals or automated equipments, as in other methods discussed earlier.

The extent of degradation determined by *in vitro* methods may differ considerably from that determined by *in vivo*. Rumen inoculum, pH, amount of protease and assumed flow rates are some of the variables that can influence the values. However, the *in vitro* methods are time saving and particularly useful in relative ranking of feeds and in evaluating the effect of heat or chemical treatment.

ESTIMATION OF AVAILABLE UDP

Assumption of a single value for the efficiency of absorption of UDP from different sources may overestimate the availability of UDP in some instances, as some feed materials may be heat damaged to some degree or contain certain natural materials that may prevent complete digestion in the intestine. The digestibility of UDP in the small intestine can be measured by *in vivo*, *in situ* and *in vitro* techniques.

In vivo techniques

In *in vivo* techniques the apparent digestibility of protein in the small intestine is estimated on the basis of protein disappearance in the intestine which is measured in animals fitted with re-entrant cannulae in the duodenum and terminal ileum. The measurements are made when the animals are given either a basal diet alone or the basal diet supplemented with different protein sources. The problems such as maintenance of the intestinally cannulated animals, length of time involved for each measurement etc., are encountered in this technique.

In situ method

In the *in situ* method, small sized nylon bags containing the protein residue after rumen incubation are incubated first in pepsin HCL solution and then inserted into the small intestine via the duodenol cannula and recovered later in faeces. The digested UDP is calculated from its disappearance values in the intestine. (de Boer *et al.*, 1987; Arieli *et al.*, 1989a). In addition to the already mentioned limitations of the *in situ* technique, other factors such as small size of the bags and rate of movement are some of the factors which may cause variations in the values determined by this techniques.

In vitro method

In the *in vitro* method, the UDP is incubated for 1-2 hours first in pepsin HCl solution and then in trypsin or pancreatin to estimate its digestibility in the intestine.

The ADF-N content of feeds has also been used to calculate the indigestible undegradable protein fractions (IUP), as a close correlation has been observed between ADF-N content and the N remaining in nylon bag residues after prolonged incubation in the rumen. The IUP is substracted from the UDP fraction to give an estimate of the potentially absorbable undegraded feed protein entering the duodenum, i.e. digestible undegradable protein (DUP) fraction. There are reports that this measure of indigestible N is not accurate for high protein supplements (Britton *et al.*, 1987). Also a modest amount of heat damage to the forage may be beneficial to the animal (Merchen and Satter, 1983). However, this is clearly an area of research to identify the amount of heat damage that can be acceptable before allowing some depreciation in protein value. This method of estimating the indigestible N in the intestine is comparatively easier, can be carried out in analytical laboratories and does not require surgically prepared animals.

ESTIMATION OF MICROBIAL PROTEIN SYNTHESIS IN THE RUMEN AND ITS DIGESTIBILITY

In vivo estimates of microbial protein synthesis in the rumen are made using animals fitted with ruminal and duodenal cannulae and are based on the assessment of digesta flow and the use of microbial markers. The accuracy of this method is influenced by the relative proportions of bacteria and protozoa in the rumen and the adequacy of markers used and requires representative sampling of both the solid and liquid phases.

Alternative estimations of microbial protein synthesis are based on the assay of the degradable OM in the rumen (using *in vitro* or *in situ* methods), assuming 32 g of microbial N/kg are synthesized of ruminally degraded OM (Arieli *et al.*, 1989b). The digestibility of microbial protein can be estimated by *in vivo* and *in vitro* techniques as in case of UDP.

Table 1 UDP in feedstuffs (g/100 g CP) (Sampath, 1990a).

Feedstuffs of high UDP (60-100% of CP)		Feedstuffs of medium UDP (30 to 59% of CP)		Feedstuffs of low UDP (0 to 29% of CP)	
Bajra (pearl millet)	68	Brewers grain	53 (48-61)	Barley	18(11-27)
Blood meal	79 (76-81)	Canola meal	31 (26-37)	Exp. Proc. Coconut cake	28
Sol. extr. coconutcake	76 (70-81)	Corn ground	41 (31-52)	Gingelly cake	24 (10-43)
Coffee seed cake	82	Cotton seed cake	49 (35-70)	Gram Chuni	18
Corn grain,cracked	81 (71-87)	Fish meal	59 (40-70)	Lupin meal	24
Feather meal	84 (83-86)	Groundnut cake	32 (6-38)	Niger cake	19 (16-23)
Fescue pasture	72	Horse gram	43	Oats, grain	18 (14-20)
Mahuva seed cake	75	Karanja cake	47	Rape seed cake	25 (10-46)
Meat meal	61 (53-76)	Linseed meal	35 (11-45)	Silk cotton seed cake	22
Rice bran	62	Meat and bone meal	53 (49-70)	Sunflower cake	15
Sorghum grain	75	Mesta seed cake	43	Wheat grain	25 (20-36)
Alfalfa, dehydrated	60 (57-69)	Rubber seed cake	31	Wheat bran	27 (23-33)
Subabul	68 (51-75)	Ricebran, deoiled	56	Alfalfa,fresh	24 (21-27)
(Leucaena leucocephala)		Safflower cake	39	Alfalfa,silage	23
		Soyabean meal	34 (10-50)	Barley silage	18
		Tobaco seed cake	57	Corn silage	24 (11-31)
		Toria seed cake	57		
		Alfalfa hay	33 (22-43)		
		Cornfodder, fresh	41		
		Cow pea fodder	32		
		Guineagrass	60		
		Oats fodder, fresh	49		
		Para grass, fresh	52		

Note: figures in the bracket indicate the range of values reported in the literature, when only one value is known, no values in brackets are given.

Table 2 Digestibility (%) of UDP in different feedstuffs, based on ADIN contents.

CONCENTRATES		ROUGHAGES	
Barley	75	Alfalfa hay	70
Blood meal	95	Alfalfa dehydrated	79
Brewers dried grain	76	Berseem	64
Coconut cake expeller	92	Corn silage	60
Corn grain	84	Cow pea	50
Corn gluten meal	89	Guinea grass	83
Cottonseed meal, decorticated	93	Maize fodder	46
Distillers dried grain	71	Rice straw	73
Gingelly cake	90		
Groundnut cake	95		
Meat meal	95		
Meat and bone meal	81		
Rice bran deoiled	79		
Sorghum grain	72		
Soyabean meal	90		
Wheat bran	93		

Source: Sampath (1990b) and Negi et al. (1988).
Values are averages.

UDP VALUES OF COMMONLY USED FEEDSTUFFS AND THEIR DIGESTION COEFFICIENT

The average UDP values for some of the commonly used feedstuffs are given in Table 1, based on a recent review (Sampath, 1990a). These values are calculated for a flow rate of 5%/h. The feedstuffs are divided into three categories of high, medium and low UDP values. Feed materials of animal origin and heat processed feed materials usually have high UDP content.
The information regarding the digestibility of UDP in the small intestine is more limited. The digestion coefficients of UDP of some commonly used feedstuffs based on their ADIN content (Sampath, 1990b) are given in Table 2. The digestibility of UDP of most of the concentrates is about 90% whereas that of roughages varies from 40 to 85%.

CONCLUSIONS

The traditional method of measuring DCP in feeds does not represent the actual protein absorbed from the feed in ruminants nor does it recognize the relationship between the N required and the energy intake. The newer protein evaluation systems are based on the amount of the UDP and microbial protein available for absorption in the small intestine. The *in situ* and *in vitro* protease enzyme methods of estimating UDP are simple and easier from the laboratory point of view. The determination of indigestible N content of feeds using ADIN values is easier than the estimation of digestibility of UDP by *in vivo, in situ* or *in vitro* procedures. However more studies are required to determine the accuracy of this method by comparing the values with those obtained by other methods. Estimation of microbial protein synthesis based on OM digested in the rumen is simpler and easier than the use of *in vivo* methods. Feed materials of animal origin and heat processed feed materials usually provide higher UDP than non-processed proteins from vegetable origin. The intestinal digestibility of UDP is gnerally higher for concentrates than for roughages. There is a wide range in UDP content of feed stuffs as reported from different laboratories. This variation may be caused by processing of the feeds, laboratory techniques, varietal or management differences. Therefore separate estimates of UDP content of the same feed stuff which has been subjected to different processing techniques are required to be undertaken. Limited information is available with regard to UDP content of various agro-industrial byproducts, commonly used in feed compounding industry which needs the attention of research workers.

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RELEVANCE OF THE RDP/UDP SYSTEM FOR FEEDING OF RUMINANTS IN THE TROPICS WITH EMPHASIS ON STRAW BASED DIETS

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SUMMARY

The system of protein evaluation based on RDP/UDP values as proposed by ARC and later adopted by NRC, considers the microbial needs for rumen degradable protein (RDP) and the host's need (at the tissue level) for absorbed amino acids derived from microbial protein and the undegraded dietary protein which escapes rumen fermentation. Microbial protein synthesised in the rumen is a function of energy made available as ATP from the fermentation of dietary carbohydrates. Insufficient extraction of energy by microbes from cell wall rich crop residues results in limited energy availability for rumen microbial growth. The N degradability of straw in the rumen is reported to be 50-60%, but the inherently low N values of straw makes the RDN availability also a limitation. From available literature, it was calculated that one kg of wheat straw on DM basis could supply 3.1 g of RDN, 2.5 g of UDN and 6.1 MJ of ME. The corresponding values for urea treated straw worked out as 8.75 g of RDN, 3.75 g of UDN and 7.6 MJ of ME/kg DM. Untreated straw fed as a sole diet cannot meet RDN and ME requirements for maintenance of a 200 kg heifer or a 400 kg lactating animal. Feeding of urea treated straw as a sole diet can provide extra nutrients (RDN, ME) for 100-150 g of live wt gain/day to a 200 kg calf, or can provide extra nutrients for yielding 2-3 kg of milk/day from a 400 kg cow. For such a cow, supplementation of untreated straw with 4 kg of concentrate could provide sufficient RDN and ME to yield 5-6 kg of milk/day, whereas just one kg of concentrate is needed along with urea treated straw to achieve the same level of performance. Supplementation with 3 kg concentrate along with urea treated straw can supply sufficient RDN and UDN but ME for producing 10 kg of milk/day. Feeding of proteins of low degradability may supply insufficient protein and energy for achieving higher yields.

INTRODUCTION

The unique feature of ruminants is that they have two types of nutrient requirements; a) to satisfy the needs of the rumen microbes, b) to satisfy the needs of the animal tissues. Satisfying the needs of the microbes helps to satisfy the needs of the host animal, because the microbial protein produced in the rumen makes a large contribution to the protein supplied to organs and tissues. In the qualitative sense, the two

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requirements differ, in that the rumen microbes can be satisfied with ammonia as a source of N, while organs and tissues need amino acids. Awareness of these differences has led to the development of protein evaluation systems, based on the concept of (true) protein absorbed from the small intestines, elaborated in this workshop by Sampath *et al.* (1993).

Both the U.K. (ARC, 1980, 1984) and the US (NRC, 1982) have developed systems based on Rumen Degradable Protein (RDP)/Undegraded Dietary Protein (UDP) values in feeds and their requirements by animals. These systems recognise that the microbes in the rumen need RDP and the host animal uses at the tissue level the absorbed amino acids that are derived both from microbial protein and UDP. The conditions of the countries where the UDP/RDP were developed are in sharp contrast to the conditions existing in tropical regions but the number of countries in which systems based on CP or DCP are replaced by such new systems is increasing. This paper evaluates the relevance of such a system to India and other tropical countries, especially for diets containing large amounts of straw.

EFFICIENCY OF MICROBIAL GROWTH ON STRAW DIETS

Amino acid requirement at the tissue level of the host ruminant is primarily met through microbial protein synthesized in the rumen. Microbial growth (i.e. protein synthesis) in the rumen depends on:
- the supply of nitrogen from NH_3 as well as preformed amino acids,
- the supply of rumen digestible energy, carbon sources for amino acid synthesis,
- phosphorous and sulphur sources.

The efficiency of microbial synthesis is related to the amount of energy which is liberated as ATP during the fermentation of carbohydrates in the rumen to VFAs. Several workers have calculated the microbial N yield/kg OM apparently digested in the rumen (DOMR) and the mean value from 262 diets came to 32 g of microbial N/kg DOMR (Harrison and McAllen, 1980). ARC (1984) has adopted the Figure of 30 g N/kg DOMR to compute the RDN requirement for ruminants.

The major source of energy for rumen microbes on a straw diet is provided by cell wall carbohydrates. The production of microbial protein is therefore related to cell wall digestibility, if other factors for microbial growth are not limiting (Hvelplund, 1989). The first limiting factor for ruminant production in the tropics is frequently the insufficient extraction of energy as VFA and ATP by the microbes from cell wall rich crop residues. Such fibrous feeds are digested only slowly in the rumen, and therefore microbial growth will be slower, also because a larger proportion of the energy extracted from the substrate is required to maintain the microbes, resulting in the reduction in microbial cell yield per unit of VFA produced (Egan, 1988). This limitation can be overcome by the careful supplementation with easily fermentable carbohydrates like sugars and starch. However, when straws are supplemented with large amounts of rapidly fermentable carbohydrate components, the result is decreased fibre digestion, through the depression of ruminal pH (Mould *et al.*, 1983/84). Also, besides energy, the rumen microbes require rumen degradable N. Most cellulolytic bacteria can incorporate non protein nitrogen (NPN) via NH_3 into cell protein (Durand, 1989).

DEGRADABILITY OF STRAW N IN RUMEN

Crude protein content in straws is generally low (about 35 g CP/Kg DM), but varies considerably between varieties (Walli *et al.*, 1988, 1990; Prasad *et al.*, 1993). The rumen availability of N from cell wall rich low N crop residues is generally considered to be quite low, as most of the N is associated with cell walls and availability then depends upon the degradability of cell walls in the rumen.
The degradation of protein associated with cell walls, as in crop residues, is difficult to measure, due to the microbial contamination of feed residues left in the bags after incubation in rumen (Varvikko and Lindberg, 1985; Negi *et al.*, 1988). To avoid the contamination effect due to microbes, Kristensen *et al.* (1982) used N^{15} labelled straw to show an effective degradability of 61% for protein in untreated straw, at a passage rate of 5%/hour. Using N free cellulosic material as a control to make correction for microbial N contamination, Negi *et al.* (1988) reported 52.5% and 37% effective degradability for total N in wheat and rice straw respectively, at an outflow rate of 2.5%/hour. These results are in contrast with the general assumption that in rumen availability of N from cell wall rich and low N crop residues is low.

Concerning the form of nitrogen present in straws, Hvelplund (1989) reported that in straws a substantial amount of N is present as protein and amino acids. Of the total N present in barley straw, amino acid N contributes 50.6%. Oosting *et al.* (1990) reported that 51.5% of the total N in paddy straw is present as neutral detergent insoluble N (NDIN) with a true digestibility of 54% for this fraction (Table 1). From the above discussion it appears that the N availability to microbes from a straw diet may not be adequate for microbial growth. Addition of RDN to such diets may prove beneficial to the microbes and consequently to the host animal.

Urea/ammonia treatment not only increases the fibre digestion of straw but also its N content. Singh and Negi (1985) reported higher ADIN (Acid Detergent Insoluble N) for treated straw than for untreated straw.

RELEVANCE OF SUPPLEMENTING A DIET WITH UDP AND ITS AVAILABILITY FROM STRAW

Beneficial aspects of feeding protein of low degradability to ruminants

In ruminants, the microbial protein synthesized in the rumen is the major protein source utilized for body functions. However, higher growth rates and milk production levels, require higher protein : energy ratios then usually provided from microbial growth alone. Supplementation with undegradable dietary protein may enhance growth rate and milk production, especially under conditions of higher levels of production. Egan (1986) explained that the enhanced growth or milk production is mediated by:

- dietary protein intact or as peptide delivered to the lower tract can improve the amino acid availability for lean tissue,
- slow degradation of proteins can result in a more constant N supply to the rumen which may improve the supply of NH_3 and possibly peptides for the growth and fermentative activity of rumen micro-organisms, thus improving the supply of microbial protein to the lower tract,
- the extra amino acids absorbed as a result of feeding more ruminal escape protein may be used with high efficiency as an amino acid source for body protein synthesis, but they may also alter the hormonal balance e.g. between growth hormone and insulin and improve growth through lean tissue growth. Similarly, beneficial effects of UDP supplementation to cows in early lactation could also be due to alteration in the hormonal concentration of insulin and growth hormone apart from providing more amino acids to the mammary gland. Lower insulin and higher growth hormone levels are likely to favour tissue mobilization of fat and increase milk production (Walli and Mudgal, 1988).

The quality of undegraded protein from straws

The amount of undegraded protein entering the small intestines (SI) on straw diets is limited. A high proportion of this is cell wall bound protein and of low digestibility in SI (Hvelplund, 1985). The technique of mobile nylon bag, containing the rumen undegraded residue, after removing the microbes attached to feed particles and inserting through abomasum was used by Hvelplund (1985). Table 2 compares digestibilities in rumen and small intestine and indicates a low quality availability of undegraded protein in untreated and ammonia treated barley straw in the lower tract. Negi *et al.* (1988) found that while the N degradability of rice straw was lower than wheat straw, DUN (Digestible undegraded N = UDN - ADIN) was almost 5 times higher in rice straw than in wheat straw (Table 1). Calculated on this basis, the net absorbable N (RDN x 0.8 x 0.75 + DUN) from rice straw was found to be almost double that of wheat straw. Kumar and Walli (1989) observed that the flow rate of ADIN at the abomasum as a percentage of N intake was significantly higher

Table 1 Fractionation of total N in straws (g/kg DM).

N fraction	Rice straw I*	Rice straw II**	Wheat straw**
Total N	7.8	6.37	5.36
NDS-N	3.8(48.7%)	-	-
NDI-N	4.0(51.3%)	-	-
RDN	-	2.35(37%)	2.81(52.5%)
UDN	-	4.02	2.35
ADIN	2.2	1.07	1.77
DUN (dig. undegraded dietary N)	-	2.95	0.58
Dig UDN (%)	-	73.47	24.66
Dig NDIN (%)	54.0	-	-
Net absorbable N = (RDN x .8 x .7 + DUN)	-	4.27	2.15

* Oosting et al. (1990); ** Negi et al. (1988)

Table 2 N content, ruminal degradability and N digestibility in intestines for untreated and ammonia treated barley straw.

	Untreated Barley straw	Ammonia treated Barley straw
N content (% of DM)		
Straw	0.48	1.32
Rumen undegraded residue	0.37	0.72
Rumen disappearance (% of intake)		
DM	24	44
N	41	70
Intestinal disappearance (% of amount entering)		
DM	5.0	7.4
N	31.7	35.7

Source: Hvelplund (1989).

Table 3 Calculated values for RDN and UDN (g/kg DM) and ME (MJ/kg DM) for untreated and urea treated wheat straw and normal concentrate.

	Untreated straw	Urea treated straw	Normal concentrate
CP	35	80	200
Total N	5.6	12.5	32
N Deg. (Rumen %)	55	70	70
RDN	3.1	8.75	22
Digestible RDN (RDN x .8 x .75)	1.86	5.25	13.20
UDN	2.5	3.75	10
Dig. of UDN in SI (%)	30	35	90
Available UDN (or DUN)	0.75	1.3	9
Net absorbable N (Dig. RDN + DUN)	2.61	6.55	21.3
TDN	400	500	700
ME = (TDN x 15.23)	6.1	7.6	10.7

($P < 0.01$) for the urea treated wheat straw diet than for the untreated straw diet. The flow rate of non-ammonia N (as % of N intake) was similar on untreated wheat straw supplemented with formaldehyde treated groundnut cake compared with the urea treated straw supplemented with untreated cake, but the flow of -amino N (as % of N intake) was lower on the latter diet, which was due to the higher ADIN content in the undegraded N fraction from urea treated straw.

CALCULATIONS OF RDN, UDN AND ME AVAILABILITY FROM STRAW BASED DIETS

On the basis of the limited data available, the average values for the availability of nutrients viz. RDN, UDN and ME of straw DM have been worked out (Table 3). Of course, the more important protein fractions available to the host animal are the digestible UDN and RDN (RDN x 0.8 x 0.75) considering 20% of microbial acid N, and the digestibility of microbial protein as 75%. Thus, 1 kg of wheat straw DM could supply 3.1 g of RDN or 1.86 g of dig. RDN and 2.5 of UDN or 0.75 g of DUN (digestible undegraded N) apart from 6.1 MJ of ME. Similarly, the Figures were worked out for the urea treated wheat straw as, 8.75 g of RDN or 5.25 g of dig. RDN and 3.75 g of UDN or 1.3 g of dig. UDN and also 7.6 MJ of ME/kg of the DM.

In India and other tropical countries, livestock farmers with meagre resources and with a shortage of green fodder, mostly use straws and very little concentrates to feed their animals. An excercise was done to see how far these diets are able to supply the nutrients for growth and milk production with respect to ARC (1980) recommendations.

Nutrient supply from straw based diet for a growing animal

For the purpose of calculations and as a case study, an animal weighing 200 kg was considered. The maintenance requirements of such an animal are 36 g of RDN and 29 MJ of ME as per ARC (1980). The nutrient availability from straw based diets when either untreated or urea-treated straw is used as the basal feed for such an animal is given in Table 4. Feeding untreated straw as a sole diet supplies inadequate RDN and ME even to meet the maintenance requirement of the animal. However, when urea treated straw is fed as a sole diet to such an animal, it supplies adequate nutrients to support a growth rate of 100 - 150 g/day.

Supplementation of the untreated straw with 1 kg normal concentrate still does not provide nutrients for maintenance, RDN being short by 6 g, which could be met by feeding a little bit of green forage to the animal or by adding some urea in the concentrate. Supplementation with 2 kg concentrate supplies sufficient nutrients to support a growth rate of 250 g/day and the supplementation with 3 kg provides sufficient RDN but insufficient ME to support a growth rate of 500 g/day.

With urea treated straw, supplementation with just 0.5 kg of concentrate 10.5 MJ ME/kg will supply enough RDN and ME to support a growth rate of 250 g/day at a body weight of 200 kg, supplementation with 1.5 kg concentrate supplies enough RDN but insufficient ME for a 500 g/gain/day growth rate, which could be compensated by a little bit of greens or increasing the ME of the concentrate.

Table 4 RDN, UDN and ME availability from straw based diets for an animal weighing 200 kg.

DMI through feeds			DMI kg/100kg B.wt.	RDN (g/day)	UDN availability (g/day)	ME (MJ/d)	Sufficiency of RDN, ME and expected growth rate
Straw	Conc.	Total					
Untreated straw and concentrate							
3.6	-	3.6	1.8	11.2	2.7	22	(RDN, ME, less for maintenance)
3.3	0.90	4.2	2.1	30.0	10.6	29.7	(RDN less for maintenance)
2.6	1.80	4.4	2.2	47.7	18.2	35.7	(Both sufficient for 250 g/day gain)
2.1	2.7	4.8	2.4	65.9	24.3	41.7	(ME less for 500 g/day gain)
Urea treated straw and concentrate							
4.4	-	4.4	2.2	38.5	5.7	35.0	(Both sufficient for 150 g/day gain)
4.15	0.45	4.6	2.3	46.2	9.4	36.0	(Both sufficient for 250 g/day gain)
3.45	1.35	4.8	2.4	60.1	16.7	40.6	(ME less for 500 g/day gain

Nutrient supply from straw based diets for a lactating animal

Considering a 400 kg cow, it requires 58 g of RDN and 46 MJ of ME for maintenance. The nutrient availability from the diets containing either untreated straw or the treated straw as the basal feed is given in Table 5. On an untreated straw diet alone, the animal receives only 20 g of RDN and 39 MJ of ME, which is insufficient to meet the maintenance requirements of the animal. If the animal is fed urea treated straw as the sole diet the animal receives enough RDN and ME for 2-3 l of milk production per day.

By supplementing the untreated straw with 0.5 kg concentrate, there is enough ME, but insufficient RDN for the above mentioned cow. Addition of 30 g of urea in the concentrate or sprayed as a solution over the straw is the cheapest way to meet the full requirement of RDN for maintenance. Alternatively, the animal has to be provided with at least 5 kg of fresh leguminous fodder to meet its maintenance requirement RDN (30 g urea = 70 g CP, 5 kg fresh legume = 0.5 kg dry = 100 g CP) Supplementation with 4 kg of concentrate along with untreated straw could provide just sufficient RDN and ME required for producing 5-6 l of milk per day. For higher milk production (about 10 kg) green fodder such as berseem in the Northern region of India may be supplied to meet the energy requirement of the animal, alternatively, the proportion of ME in the concentrate need to be increased.

Urea treated straw, supplemented with 1 kg of concentrate, provides enough RDN and ME to meet the requirement for an animal of 400 kg BW to produce 5 l of milk per day. As also stated above, UDP is not required at these levels of production. Supplementation with 3 kg of concentrate per day can meet the RDN requirement for 10 l of milk per day, but the ME availability becomes limiting, which need to be compensated by providing some green fodder like maize and/or by increasing the proportion of ME in the diet.

- Metabolizability of feeds: ARC (1980) suggests that for an animal weighing 100 kg and growing at 0.5 kg/d, the RDP/UDP ratio changes from 88 : 12 to 73 : 27 and the requirement for total protein (RDP + UDP) from 270 g to 260 g/d, as the metabolizability of the feed (ME/GE) increases from 0.4 to 0.7. The slight decrease in total protein requirement could be explained by the better digestibility of UDP than the microbial protein arising from RDN in the rumen.
- Growth: NRC system uses the term DIP (degradable intake protein) and UIP (undegradable intake protein). As per ARC (1980), an animal of 200 kg LW and gaining up to 500 g/day can meet all its protein requirement from RDP alone, whereas NRC (1989) recommends 87% DIP and 13% UIP (Table 4). The CP and ME requirements suggested by NRC are higher than ARC, however, the ratio of CP/ME is higher for ARC than for NRC.
- Milk production: With regard to milk production, also, the RDP : UDP ratio in the diet has been suggested to vary from 85 : 15 to 80 : 20 as the metabolizability of the diet increases from 0.5 to 0.7 for a cow weighing 400 kg and yielding 10 litres of milk/day of 4.9% fat. At the ME/GE ratio of 0.5 in the diet, a cow yielding 5 l of milk/day, could meet all its CP requirement through RDP, alone as per ARC recommendation, however, the NRC system recommends a ratio of 60 : 40 for DIP and UIP in the diet at all levels of milk production (Table 4). As in the case of growth, similarly for milk production, the CP and ME requirements suggested by NRC (1989) are higher than ARC (1980) and the CP/ME ratio is also much higher than as per ARC recommendations. For a cow weighing 400 kg and yield 10 l of milk/d of 4.5% fat and maintaining its weight, the CP and ME requirements were 965 g and 103 MJ and giving the ratio of CP/ME as 9.4 as per ARC (1980). However, the NRC (1989) requirement for a cow which is gaining 225 g/day in addition to yielding 10 l of milk/d of 4.5% fat was 1479 g of CP and 112.5 MJ of ME giving a ratio of CP/ME as 12.2.

  Utilization of body reserve in case of dairy: Both the ARC and NRC standards take into consideration the physiological status of the animal, with regard to weight gain or loss, pregnancy, fat and protein percent of milk, endogenous N-losses and N required for hair and scurf. Since milk production gets metabolic priority during lactation, there is a considerable demand for nutrients by the mammary gland. High yielding animals that do not receive enough nutrients from the feed will supply the demands of the mammary gland for extra nutrients through mobilization of body reserves (90% fat and

Table 5 RDN, UDN and ME availability from straw based diets for a cow weighing 400 kg.

DMI through feeds: Straw	Conc.	Total	DMI kg/100 kg B. wt.	RDN availability (g/d)	UDN availability (g/d)	ME availability (MJ/d)	Sufficiency of RDN, ME and expected milk yield
Untreated straw and concentrate							
6.75	0.45	7.2	1.8	30.8	9.1	46.0	(RDN too low for maintenance)
7.05	1.35	8.4	2.1	51.7	17.5	57.4	(ME enough for maintenance)
6.5	2.70	9.2	2.3	79.5	29.2	68.5	(ME slightly too low for yield of 5 l of milk/day)
Urea treated straw and concentrate							
8.8	-	8.8	2.3	77.0	11.5	66.9	(Both RDN and ME sufficient for 2-3 l/day)
8.3	0.90	9.2	2.3	92.4	18.9	72.7	(Both RDN and ME sufficient for 5 l/day)
7.7	2.7	10.4	2.6	126.8	34.4	87.4	(ME less for 10 l of milk/day

Table 6 Nutrient requirements for growth and milk production (ARC versus NRC).

FOR A GROWING ANIMAL WEIGHING 200 KG

Nutrient fraction	Levels of growth rate (g/d): Zero	250	400	500
ARC				
RDN (g/d)	36	46.4	-	61.6
UDN (g/d)	-	-	-	-
CP (RDP + UDP) (g/d)	225	290	-	385
ME (MJ/d)	29	37	-	50
CP (RDP + UDP)/ME	7.7	7.8	-	7.7
NRC				
DIP	-	-	262.5	281.3
UIP	-	-	23.1	41.3
DIP+UIP	-	-	285.6	322.6
DIP/UIP	-	-	92/8	87/13
CP	-	-	362.5	400.0
ME	-	-	52.8	57.3
CP/ME	-	-	6.86	6.98

FOR A LACTATING ANIMAL WEIGHING 400 KG

Nutrient fraction	Levels of milk production (l/d): Zero	5.0	6.5	10.0	13.5
ARC					
RDN	58	92	-	131.0	-
No gain UDN	-	-	-	23	-
In body RDN/UDN	-	-	-	85/15	-
Weight CP	362.5	575	-	962.5	-
ME	46	74	-	103	-
CP/ME	7.88	7.77	-	9.34	-
NRC					
225 g DIP	-	-	706	-	1075
LWG/d UIP	-	-	465	-	712.5
DIP/UIP	-	-	60/40	-	60/40
CP	-	-	11171.2	-	1787.5
ME	-	-	93.6	-	131.7
CP/ME	-	-	12.5	-	13.57

10% protein), resulting in negative energy balance and weight loss, especially during early lactation. Feeding of bypass protein in such a situation could provide extra amino acids for the balance of nutrients or could enhance mobilization through increased growth hormone level.

FEEDING OF SLOWLY DEGRADABLE PROTEIN AND SUBSEQUENT EFFECT ON NUTRIENT UTILIZATION

Feeding of diets of lower protein degradability viz. fish meal and formaldehyde or heat-treated meals has been found to decrease the OM digestibility compared to the diets of higher RDP value (Zerbini *et al.*, 1988). However, nutrient digestibilities were also reported to be similar when feeding diets containing variable RDP/UDP ratio (Peterson *et al.*, 1985; Kennelly *et al.*, 1986).
Growing animals that were fed with proteins of lower RDP value showed increased N retention and a simultaneous decrease in urinary N excretion than when proteins of higher RDP value were fed (Wanapat *et al.*, 1982; Kurilor *et al.*, 1988; Walli *et al.*, 1989). The N retention in lactating cows was also improved by infusion of casein into the abomasum (Cohick *et al.*, 1986). The flow rates of non-ammonia N and amino N at abomasum (as % of N intake) given in Table 7, were highest on urea treated straw supplemented with low degradable protein, followed by untreated straw plus low degradable protein and lowest on untreated straw plus highly degradable protein (Kumar and Walli, 1989).

Table 7 Flow rate of N fractions at abomasum (as % of N intake) on untreated or urea treated wheat straw supplemented with a concentrate containing either untreated or HCHO treated groundnut cake.

N fractions	Untreated straw + untreated cake	Untreated straw + treated cake	Treated straw + untreated cake	Treated straw + treated cake
NAN**	76.4 [a]	83.6 [b]	84.4 [b]	91.3 [c]
NANUN**	75.3 [a]	82.5 [b]	82.6 [b]	89.7 [c]
NADN (NANUN-ADIN)**	62.0 [a]	70.4 [b]	64.5 [a]	73.4 [b]
Amino N**	59.6 [a]	68.3 [b]	62.5 [a]	71.7 [b]

** $p < 0.01$

FEEDING OF SLOWLY DEGRADABLE PROTEIN FEEDING AND ITS EFFECT ON GROWTH PERFORMANCE

Growth rate of lambs fed straw based diets supplemented with casein (treated with HCHO) plus urea was significantly higher than those fed untreated casein (Kempton and Leng, 1979). Gupta and Walli (1987) also found a significant increase in the growth rate of kids fed formaldehyde treated groundnut cake as part of the diet. When an ammoniated wheat straw was fed along with supplements like blood meal or soybean meal, the average daily gain of animals was significantly increased relative to untreated straw (Nelson *et al.*, 1985). Kumar *et al.* (1988) observed that cross-bred heifers fed ammoniated straw supplemented with groundnut cake, treated or untreated with formaldehyde grew faster than the animals given fishmeal instead. Kumar and Walli (unpublished) measured the growth rate and feed conversion efficiency in cross-bred calves (Table 8). The efficiency of nutrient utilization for growth was better for untreated straw and slowly degradable protein than for ammoniated straw and slowly degradable protein.

Several workers conducted dose response studies on supplementation of straw diets with slowly degradable protein. Saadullah (1984) observed little benefit of fishmeal supplementation beyond 50 g/d to untreated rice straw in calves. Wanapat *et al.* (1986) reported the LWG of 0.47, 0.81 and 0.93 kg/d, when rice straw was supplemented with 1, 2 and 3 kg of concentrate containing 65.6% rice bran and 10.9% soybean meal. The increase in LWG during these experiments could be due to an increase in ME intake in addition to that of supply of amino acid at tissue level for protein synthesis. Perdok and Leng (1987) reported linear increase in live weight gain/d by supplementing NH_3 treated rice straw with graded levels of protein meal (0.4, 0.8 and 1.2 kg) largely consisting of slowly degradable protein.

Sampath *et al.* (1989) achieved an average gain of 0.5 kg/day, in cross-bred calves by supplying 25 percent more RDP and ME than recommended by ARC (1984) suggesting thereby that more studies of this nature are needed to work out the RDP, UDP and ME requirements and supply under Indian conditions. When leucaena leaf (LL) was supplemented to urea treated straw 1 kg fresh basis (205 g DM), the weight gain was significantly improved in calves (Cheva Isarakul, 1987). The medium ruminal N degradability (50-90%) of LL not only resulted in significant increase in DOMI but also doubled the quantities of dietary protein escaping the rumen, when fed at levels of 30% DMI.

Table 8 Growth rate and feed conversion efficiency for cross-bred calves fed untreated or urea treated straw supplemented with concentrate containing either untreated or HCHO treated groundnut cake

N fractions	Untreated straw + untreated cake	Untreated straw + treated cake	Treated straw + untreated cake	Treated straw + treated cake
LWG (g/d)	443	473	504	536
DMI (kg/100 kg. B.W.)*	2.4 ^{b}	2.3 ^{b}	2.6 ^{a}	2.6 ^{a}
DMI (g/kg $W^{0.75}$)**	86.7 ^{b}	82.8 ^{b}	96.6 ^{a}	95.8 ^{a}
Feed : gain (kg/kg gain)	9.4	8.0	9.5	9.2
Feed cost (INR/kg LWG)	13.8	12.5	13.9	14.2

* $p < 0.05$; ** $p < 0.01$

FEEDING OF SLOWLY DEGRADABLE (UDP)PROTEIN AND ITS EFFECT ON LACTATION PERFORMANCE

Ørskov *et al.* (1977) observed that post ruminal infusion of casein not only increased milk yield, but also significantly increased milk protein content in high producing cows, which were further increased during restricted energy intake. Post ruminal supplementation of cows with casein also increased milk yield by 1 to 4 kg/cow/day, and the milk protein yield by 10-15% in results reported by Clark (1975). Ørskov and McDonald (1981) also found an increase in FCM yield and milk protein content when cows were fed diets containing fish meal compared to ones containing groundnut cake. Similar observations were made by Forester *et al.* (1983). However, the findings of other workers did not show any increase in milk yield on diets having lower protein degradability (Erdman and Vandersall, 1984; Murphy and Kennelly, 1986). Saadullah (1984) observed a linear increase in milk yield in zebu cows when graded level of fish meal was given as a supplement to the basal diet of ammoniated rice straw. Perdock (unpublished data) found 20% increase in milk yield from 2.6 to 3.2 l/day and 8% increase in fat content when urea treated straw was supplemented with 1 kg coconut cake, possible due to the slower degradability of the coconut cake protein in the rumen. Factors like stage of lactation and the level of production may cause the variable response to feeding of slowly degradable. Oldham (1984) postulated that the response to increased input of amino acids depends both on the physiological status of a cow, i.e. the stage of lactation of the cow and the condition of body reserves and the balance of all nutrients absorbed from the gastro-intestinal tract.

CONCLUSIONS

Untreated straws contain insufficient energy and RDN even for the maintenance of the animal. The degradability of N from straw in the rumen is higher than is generally assumed. Addition of RDN to the diet helps only to achieve moderate levels of growth and milk production. At higher production levels ME becomes a limitation.

There appears to be a scarcity of data to substantiate the claim that feeding of slowly degradable proteins has beneficial effects on the animal performance in tropical countries. Thus, there is an urgent need to conduct trials using different dietary RDP:UDP ratio in straw based diets to examine the relevance of adopting RDP/UDP system of feeding low producing animals.

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A RUMEN MODEL

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SUMMARY

A rumen model is described, by which parameters as rate constant of degradation, rate constant of passage and intake can be integrated to evaluate the qualitative and quantitative values of these rate constants or to identify knowledge gaps with regard to aspects of processes of rumen degradation, rumen turnover and microbial protein and volatile fatty acid production. Applying the rumen model to data of rumen evacuation studies shows that estimates of rate of degradation derived from nylon bag studies and of rate of passage derived from marker studies were not quantitatively describing feed intake and rumen degradation. It is further described, how by use of a model approach, end products of rumen fermentation as microbial protein, volatile fatty acids and undegraded feed protein can be estimated.

INTRODUCTION

Qualitative knowledge of the ruminants digestive functions has greatly progressed over the last 30 years owing to the combined efforts of microbiologists, nutritionists, physiologists and biochemists. The process of microbial digestion resulting in production of volatile fatty acids and microbial protein has been described by various workers (Hungate, 1966; Van Soest, 1982; Czerkawski and Cheng, 1988; Preston and Leng, 1988). The rumen contains a complex mixture of food materials and micro-organisms, which includes bacteria, protozoa and fungi, many of which interact together in the process of fermenting proteins, soluble carbohydrates and cell walls. Kinetics of processes in the rumen, like rate of passage of liquid and solid phase and rate of degradation, are also studied extensively (Ørskov and MacDonald, 1979; Warner, 1981; Aitchisson *et al.*, 1986a, b, c; Tamminga *et al.*, 1989). The kinetic parameters can be integrated into a model to describe intake and ruminal digestion.

A RUMEN MODEL

The capacity of the ruminant animal to ingest, digest and absorb nutrients is controlled by various factors as physiological control factors, physical limitations of and inhibitory factors in the feed. The degradation and passage of feed components and the formation of fermentation end-products in the rumen is of

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major importance in the process of feed utilization. Model descriptions of rumen turnover processes are often based on division of the rumen DM into components with differing passage and degradation characteristics. An example of such a division is given in Table 1.

Table 1 Components of rumen DM.

Component	Composition
Soluble (S)	sugars, protein
Insoluble rapidly degradable (IR)	starch, "storage" protein
Insoluble slowly degradable (IS)	cellwalls, protein associated with cellwalls
Insoluble undegradable (IU)	cellwalls, protein associated with cellwalls

All components have their own rate of degradation (R_d). S has a very high k_d, while IU has a k_d of zero. Fractions IR, IS and IU could be further subdivided into a large and small particle fraction. For cattle particles which are retained on a 1.25 mm sieve are considered to be unable to leave the rumen (Kennedy and Poppi, 1984) and have a rate of passage (k_p) of zero. The rate of passage of the S fraction wil be closely related to the rate of passage of the fluid phase.

Degradation of protein and carbohydrates in the rumen will result in production of microbial protein and volatile fatty acids (VFA), while part of the feed protein will leave the rumen undegraded and could be digested and absorbed postruminally.
Some examples of modeling of rumen processes will be described in the present paper to demonstrate the various objectives modeling can have:

- evaluation of quantitative and qualitative value of experimentally determined parameters,
- nutritional evaluation,
- prediction of nutrient availability,
- definition of research priorities.

Evaluation of experimentally determined rate constants of passage and degradation of cellwalls

A steady state situation in the rumen means that the rumen pool is constant and that the amount entering the rumen is equal to the amount leaving the rumen. In a steady state situation the rate of intake (k_i = intake/rumen pool) should thus be equal to the rate of disappearance from the rumen, which is equal to k_d + k_p, as described by Doyle (1984). This is only true if k_d and k_p are expressed as fraction of the whole rumen pool. If k_d is estimated from *in sacco* studies by a first order model k_d is the fractional rate of degradation of the potentially degradable fraction and does not refer to the whole rumen pool. A model to estimate k_d from *in sacco* data is:

$$f_t = f_s + f_d * (1-e^{kd*t}),$$

in which f_t is the degraded fraction after t hours of incubation in the rumen and f_s and f_d are the soluble and potentially degradable fraction respectively (Robinson *et al.*, 1986). If such a model is used to estimate the k_d of the cell wall fraction the f_s is zero, since cell walls are by definition insoluble. The k_d of the potential degradable fraction estimated by such a model can be converted to the k_d of the whole rumen cell wall pool by the following formula: fractional rate of degradation of the whole rumen pool (k_d') = $k_d * f_d$.

The k_p is often measured from the excretion characteristics of a marker, that is associated with the particles in the rumen. An often used method is the single dosing of chromium labeled cell walls into the rumen and measurement of the chromium concentration in the faeces at several time intervals after dosing. Preparation of the markers is described by Udén *et al.* (1980) and the mathematical procedure for estimation of the k_p by Grovum and Williams (1973). The chromium labelled particles are usually of such a size, that they are retained on a sieve of 1 mm. Kennedy and Poppi (1984) proposed, that particles in the rumen of cattle, that are retained on a sieve of 1.25 mm are not leaving the rumen. Hence, the k_p estimated by the usually used marker technique only refers to the particle pool in the rumen, that can potentially leave the rumen and not to the whole rumen cell wall pool. Approximately 30 % of the whole rumen cell wall pool of cattle consuming ammoniated and untreated wheat straw consisted of particles that were retained on a 1.25 mm sieve (Oosting, unpublished). To estimate the k_p of the whole particle pool from the k_p estimated from marker excretion the following formula should be used: rate of passage of the whole rumen particle pool (k_p') = k_p * fraction of small particles in the rumen particle pool.

In Table 2 the actually recorded cell wall intake (NDFI = neutral detergent fiber intake) is compared with the estimate based on the k_p' and the k_d' and the rumen NDF pool for two studies conducted by Aitchisson *et al.* (1986a, 1986b). The aim of the comparison was to evaluate the value of estimates of rate constants of passage and degradation for explanation of treatment effects. The predicted NDFI is ($k_p' + k_d'$) * rumen NDF pool* 24. The k_p' was calculated from the k_p by assuming that 70% of the rumen particle pool had such a size, that it could potentially leave the rumen.
Table 2 shows, that the qualitative prediction of NDFI by the model was better for the experiment of Aitchisson *et al.* (1986b) than for the experiment of Aitchisson *et al.* (1986a). Predicted and observed NDFI are significantly correlated (r = 0.913), which indicates, that the model gave reasonable relative predictions. This could, however, mainly be attributed to the high correlation between NDFI and rumen pool size (r = 0.933) and not to k_p' and k_d'. The sum of k_p' and k_d' was not significantly correlated to NDFI. The low correlation between the sum of the rate constants

and NDFI could of course be due to the application of a constant fraction of small particles in the rumen particle pool. It can, be concluded from Table 2, that estimates of k_d from *in sacco* experiments and of k_p from marker studies can not simply be used for explanation of treatment effects. Information about rumen pool size and of the average proportion of particles smaller than 1.25 mm in the rumen is required.

The fermentation of feed, especially cell wall constituents, in the rumen is controlled by the fermentation rate and passage rate of digesta (Allen and Mertens, 1988; Aitchisson *et al.*, 1986c). The rumen model could be used to estimate the rumen digestibility of nutrients. The rumen digestibility is equal to $k_d'/(k_d' + k_p')$. Table 3 gives a comparison of actually observed rumen NDF digestibility and model predictions of rumen NDF digestibility by the equation given above.

Table 2 Observed and model predictions of NDF intake.

Feed	Observed NDFI (g/day)	Rumen NDF pool (g)	k_p' (/h)	k_d' (/h)	Predicted NDFI (g/day)
Grass hay[1]					
- early cut	542	423	0.0232	0.0150	388
- late cut	661	650	0.0248	0.0091	529
White clover hay	293	282	0.0209	0.0187	268
Grass hay[2]					
- high intake no supplement	551	506	0.0281	0.0145	517
- high intake maize supplement	578	522	0.0279	0.0152	540
- low intake no supplement	367	376	0.0226	0.0131	322
- low intake no supplement	367	399	0.0219	0.0161	364

[1] Aitchisson et al. (1986a); [2] Aitchisson et al. (1986b)

Table 3 Observed and model predictions of rumen NDF digestion

Feed	Observed NDFD (g/kg)	k_p' (/h)	k_d' (/h)	Predicted NDFD (g/kg)
Grass hay				
- early cut	748	0.0232	0.0150	393
- late cut	619	0.0248	0.0091	268
White clover hay	797	0.0209	0.0187	472
Grass hay				
- high intake no supplement	626	0.0281	0.0145	340
- high intake maize supplement	601	0.0279	0.0152	353
- low intake no supplement	643	0.0226	0.0131	367
- low intake no supplement	641	0.0219	0.0161	424

Comparison of the observed and predicted rumen NDF digestibility in Table 3 leads to the conclusion, that estimates of k_d' and k_p'

from *in sacco* and marker studies underestimates the rumen digestibility, probably due to overestimation of k_p' and underestimation of k_d' as suggested by Aitchisson *et al*. (1986c). Overestimation of k_p may be caused by the fact that k_p is estimated by inert markers. Such markers are not subjected to digestion and the production of gases resulting from this digestion. Such gasproduction may reduce the functional specific gravity of feed particles and prevent them from leaving the rumen before a substantial part of the digestion has taken place. Underestimation of k_d may result from the fact that material included in nylon bags is not subjected to particle size reduction due to chewing and rumination (Tamminga, 1993).

Nutritional evaluation: estimation of RDP/UDP value of a protein

Protein in the diet is partly degraded in the rumen and its degradation is affected by factors like solubility, inhibitory substances like tannins etc. and rumen environment. Protein that escapes rumen degradation and that passes to the lower digestive tract plays an important role in high yielding animals, particularly when high biological value protein is fed to cattle. Protein escaping rumen degradation (UDP) can be calculated by using the equation

$$CP_u + (CP_t - CP_s - CP_u) * \frac{k_p}{k_p + k_d}$$

UDP = undegradable protein
CP_t = total CP
CP_s = soluble CP
CP_u = undigestible CP
k_p = rate of passage of feed protein
k_d = rate of fermentation of potentially digestible protein.

As with description of NDFI and rumen NDF digestion by the model, the accuracy of prediction of UDP depends very much on the accuracy of prediction of k_d and k_p.

Prediction of nutrient availability: microbial protein synthesis

Microbial protein synthesis is another important function of the rumen, to provide protein to the host animal when digested and absorbed from the lower digestive tract. Now it is established that on average 32 g nitrogen or 200 g microbial protein is synthesized per kg organic matter apparently digested (ARC, 1980), although considerable variation has been reported for individual experiments (Harrison and McAllen, 1980). The efficiency of microbial protein synthesis is however, related to the rate of passage. If passage is relatively slow, the turnover of microbes in the rumen is relatively high due to lysis and predatation by protozoa, which results in a relatively low efficiency of microbial protein synthesis. A quantitative relation between *in vitro* efficiency of microbial protein synthesis and rate of passage is given by Hespell and Bryant (1979).

Prediction of nutrient availability: volatile fatty acids production

The volatile fatty production in the rumen depends on the amount of OM digested. Looking into stoichiometry of hexose fermentation, we find that

$$\tfrac{1}{2}a\ C_6H_{12}O_6 \longrightarrow a\ CH_3COOH + a\ CO_2 + 4a\ [H]$$

$$\tfrac{1}{2}b\ C_6H_{12}O_6 \longrightarrow b\ CH_3CH_2COOH + b\ H_2O - 2b\ [H]$$

$$c\ C_6H_{12}O_6 \longrightarrow c\ CH_3CH_2CH_2COOH + 2c\ CO_2 + 4c\ [4H]$$

(Czerkawski, 1986).

In the above given formulas a, b and c are the molar proportions of acetate, propionate and butyrate of the total volatile fatty acids production.
Thus (4a + 4c)[H] is produced, 2b[H] is utilized for propionate production and (4a + 4c - 2b)[H] is left which is converted to methane. Molar proportions play a key role because high fibrous diets result in higher methanogenic VFA. The number of moles of glucose available for digestion in the rumen may be calculated from the whole tract organic matter digestibility (OMD) if it is assumed, that 65% of the whole tract OMD occurs apparently in the rumen (ARC, 1980) and that 1 mole of glucose in carbohydrates has a molecular weight of 162 g:

$$\frac{0.65 * DOM}{162} = \text{moles of anhydroglucose } (C_6H_{10}O_5)_n$$

(Tamminga and Van Vuuren, 1988).

An example of such a calculation is given below.

Amount of VFA produced

If a cow consumes 8 kg digestible OM, then the apparently rumen digestible OM (ARDOM) is 5 kg, and the ratio of acetate: propionate: butyrate is 70 : 20 : 10, then 5 kg ARDOM with the equivalent to 30.9 moles of $(C_6H_{10}O_5)_n$ and 0.5a + 0.5b + c = 35 + 10 + 10 = 55 moles of anhydrous glucose are required to produce 100 moles of VFA.

19.7 moles of $(C_6H_{10}O_5)_n$ = 39.4 moles of acetate

5.6 moles of $(C_6H_{10}O_5)_n$ = 11.2 moles of propionate

5.6 moles of $(C_6H_{10}O_5)_n$ = 5.6 moles of butyrate

30.9 moles of $(C_6H_{10}O_5)_n$ = 56.2 moles of VFA

Figure 1 Input of feed and output of end products.

Feed Input (5 kg ARDOM)	UDP	-	Aminogenic
	Microbial protein	1000	Aminogenic
	Moles of acetate	39.4	Ketogenic
	Moles of propionate	11.2	Glucogenic
	Moles of butyrate	5.6	Ketogenic
	Digestible micro lipids	-	-
	Digestible feed lipids	-	-

Finally, the input and output from the rumen of a cow consuming 5 kg ARDOM in totality has been presented in Figure 1. The feed coming into the rumen consists of CP, carbohydrate, lipids, minerals and vitamins. CP in the rumen is partly degraded to ammonia which is utilized for microbial protein synthesis and partly escapes from the rumen as UDP. Both UDP and microbial protein are aminogenic. Carbohydrates are fermented to VFA, while acetic acid and butyric acids are ketogenic and propionic acid is glucogenic. In addition to microbial protein and VFA some amount of digestible microbial lipids are synthesized.

CONCLUSIONS

A simple rumen model as described here is a tool for integration of feed evaluation parameters. Rumen digestibility, microbial protein synthesis and volatile fatty acid production can be calculated from *in sacco* data in combination with the rate of passage or from the whole tract digestibility. Another aim of a rumen model is to evaluate the value of parameters estimated by various methods. As described in this paper the rate of passage estimated by a marker technique is probably an overestimation and the rate of degradation estimated *in sacco* is probably an underestimation. Many qualitative and quantitative relationships in the rumen are unknown. Modeling could give directions for research, by defining the most important gaps of knowledge.

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THE COW MODEL, A MANAGEMENT TOOL FOR RUMINANT FEEDING

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SUMMARY

A model is proposed for the prediction of animal production at a given amount and quality of feed in lactating cows based partly on NRC formulae for dry matter intake (DMI) and nutrient requirements. This model was used on data gathered from farmers in the Pune district of Maharashtra, to estimate production performance from the observed availability of feeds. A wide range of nutritive values was assumed for feeds available, and varying concentrate levels were included, to predict the number of lactating cows and their production that could be supported under different options. Predicted values related well with actual field observations: predicted number of animals were 2 and 6. Predicted production was 5200 l versus 5500 in actual observations. The possible reasons for the differences include errors in (i) the data gathered, (ii) assumptions on requirements of animals, and (iii) the DMI prediction formula, especially the part dealing with the substitution rates. More information on experiments conducted with crop residues needs to be analysed to improve the accuracy of the model. The study was further intended to assess the effects of selective consumption of roughage on number of animals and their productivity. With an assumed increase of 5 units in TDN content due to selection the milk production per animal increased by 12%. The model needs to be refined but can be used to assess the effect on herd composition and individual production of innovations that are discussed elsewhere in these proceedings i.e. straw treatment as well as effects of breeding or management for straw quality and or straw quantity.

INTRODUCTION

Large variations are seen in the type and size of cattle maintained by farmers in India. Indian farmers adopt traditional methods in selection, preparation, and mixing of feeds in a wide array of feeding practices (Pradhan *et al.*, 1993). Formulation of rations for these conditions is seldom done by the extension workers/nutritionists on a short term trial and error basis but it is also necessary to advise farmer(s) on the long range planning of the (dairy) farm activities. This involves complex calculations which take into consideration a large number of variables. With the advent of computers such calculations do not pose much of a problem anymore and a need is felt to develop suitable models, so called management support models. Such models

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translate the ration formulation principles into practical guidelines as discussed in the papers during the farming systems session of this workshop (Sitaramaswamy and Jain, 1993; Vijayalakshmi *et al.*, 1993; Patil *et al.*, 1993a, b). The modeling approach needs still much refinement but can be used to help guide the research priorities and also the extension programs; although presently with low accuracy. The primary information needed for such an exercise in terms of inputs includes:

- nutrient requirements of animals for maintenance, production etc.,
- nutritive value and other characteristics of the feeds,
- availability of feeds vis-a-vis the animal performance.

The current state of knowledge on feeding standards in the tropics is still not complete (Ranjhan and Singh, 1993; Ranjhan, 1993). Differences in nutrient requirements are noted between feeding systems and differences in feeding value between species are also reported. Feeding values of commonly available tropical feedstuffs are reviewed by Prasad *et al.* (1993a, b). It may be concluded from their data that a large variation exists in the nutritive value of crop residues which form the bulk of the feeding rations in tropical countries like India. The information on voluntary dry matter intake (DMI) of the low quality roughages is inadequate and use of equations for prediction of DMI designed for conditions of so called developed countries can at best be taken as first approximations, since crop residues are hardly used as feeds in those regions (Forbes, 1988). Further these equations do not have a high predictive ability for the commonly used feedstuffs in these countries.
In view of the foregoing discussion it would be necessary to make assumptions on the basis of currently available data in order to develop a model for ruminant nutrition. This study presents an attempt in that direction. The resulting model has been applied to case studies that test the possible effects of changes in the management practices. The design and testing of such models also assist in the identification of gaps in knowledge and research priorities.

ASSUMPTIONS

Energy requirements

The requirements of energy for lactating cows are assumed to be 35 g TDN/kg$^{0.75}$ for maintenance, and 322 g TDN/kg fat corrected milk (FCM) (NRC 1988, update 1989).

Crude protein requirements

CP requirements for maintenance are assumed to be 6 g/kg$^{0.75}$ and 80 g/kg FCM. No specification was made for requirements of RDP or UDP (Walli *et al.*, 1993; Sampath, 1993).

Dry matter intake

The DMI was calculated with the following equation:

$$DMI = 5.4 * W / (5(100\text{-}TDNR)) + (TDNR/100) * .3FCM + (1\text{-}(1 + C/50) * (100\text{-}TDNR) / (100\text{-}TDNC)) *.5C$$

Where:

BW	=	bodyweight (kg)
TDNR	=	TDN content of roughage (%)
TDNC	=	TDN content of concentrates
FCM	=	fat corrected milk production (kg/day)
C	=	quantity of concentrates fed (kg/day).

The forage intake is taken to depend on forage quality and the equation 5.4 * W / 5(100-TDNR) was taken from NRC (1988). It should be noted that this equation gives reasonable predictions for low and medium quality of roughages, but because of exponentiality of the equation, the prediction for high quality roughage seems to be overestimated. The second part of the equation is included in order to account for the stimulation of intake by milk production. According to ARC (1980) each unit increase in FCM increases the DMI by 0.2 kg at an average TDN content of 65%. Hence the coëfficient for FCM was put at 0.3 per kg of TDN intake. It is known that supplementation of forages with larger quantities of concentrates will substitute forage at an increasing rate (Prasad *et al.*, 1993a). A further assumption is that substitution is essentially a function of the indigestible matter, which is expressed here with a factor (100-TDNR) / (100-TDNC). The substitution rate of indigestible matter was arbitrarily set at 0.5 based on the assumption that ground concentrate would only partly replace forage. The model predicts that SR will be higher for better as compared to lower quality roughages which agrees with ARC (1980), Ketelaars and Tolkamp (1991) and Prasad *et al.* (1993a). The increase in the SR with increased concentrates supplementation is thought to result from the pH decreasing effect resulting in reduced cell wall degradation; a situation where cell wall primarily present in forages will take up more space in the rumen. To introduce this increase in the equation the part (1 - (1 + c/50) was, also for a case study somewhat arbitrarily chosen. (This approach is based mainly on the assumption that physical factors like rumen fill determine intake. The use of alternative theories such as from Ketelaars and Tolkamp (1991) can be considered in a later stage.)

Feed availability

Information on the feed availability for the two case studies was obtained from a survey conducted in the Pune district of the state of Maharashtra. This survey involved 114 farmers of different socio-economic status. Each farmer was visited every 15 days to record the quantity of feeds offered and the animal performance (Joshi *et al.*, unpublished). The salient findings are given in Table 1.

Table 1 Feed availabilty and herd composition of farmers.

Category	Small farmer	Large farmer
Herd (units of 400 kg)		
Young	0.50	1.50
Milking	1.19	2.57
Dry	0.44	0.81
Working	0.23	1.81
Total	2.36	6.69
Feed resources, kg of DM/year		
Self grown forage	1300	16.400
Concentrate	900	2.300

THE USE OF THE MODEL FOR TWO CASE STUDIES

The proposed model made it possible to predict the DMI by the equation described earlier and to compare the predicted animal performance with the actual performance recorded through the survey. The TDN content of forage was varied from 35 to 60% with increments of 5 units. The CP content was assumed to range between 2.5 and 15% with increments of 2.5 units. The CP intake of the animals was balanced by using concentrates with a TDN content of concentrate of 65%. The concentrate supplementation was further allowed to vary from 0 to 10 kg per day per head.

The proposed model was used to suggest alternative approaches for each farmer category to improve the animal and/or the herd performance. Two approaches to increase the milk production are used, i.e. to increase the production from a given number of animals (case I), or from a given quantity of feed (case II). The first approach is more applicable to small farmers conditions since small farmers may not be in a position to reduce the number of animals. The second option is more useful for large farmers as there is a possibility to maximize the milk output by reducing the number of milking animals.

Case I: large farmer

With each of the variables indicated earlier, the expected DMI was computed. By assuming that the large farmer also will keep the non-milking stock, the number of animals that could be supported was calculated. The data of Table 2 indicate that the number of animals predicted with the model are less than the actual number of animals kept by the farmers.
Some reasons for underestimation of the number of animals could be:

- errors in the estimation of requirements of non-lactating animals, primarily due to assumed average weights, or variable requirements for maintenance or production,
- the body weight of the lactating animals was assumed to be 400 kg for calculation of nutrient requirements. The actual bodyweights of the animals maintained by the farmers may have been less resulting in lower requirements. When the bodyweight

of adult lactating cows for the estimation of nutrient requirement was assumed to be lower (350 kg versus 400 kg), the number of animals that could be supported on the farm increased to between 1.8 to 2.2 for different forage TDN contents. Because this was closer to the actual number, the further calculations were done on the basis of 350 kg animals,
- errors associated with the prediction of DMI from the proposed formula. The substitution rate predicted by the formula was lower than reported values by Prasad *et al.* (1993a),
- inaccurate estimates or measurements of feed availability and or milk production.

Table 2 Number of animals supported with available DM at different TDN values.

		Estimated no.	
Roughage TDN	Actual no.	400 kg LW	350 kg LW
60	2.57	1.7	1.8
55	2.57	1.8	2.0
50	2.57	1.8	2.1
45	2.57	1.8	2.2
40	2.57	1.7	2.2
35	2.57	1.6	2.0

On the feed with a TDN of 40-45% and available concentrate allowance of 2300 kg it would be possible to achieve a milk production of 3000-5000 kg per year/herd (Table 3). The average daily DMI recorded was 7.9 kg while the total annual production of the herd was 4830 kg which suggests that actual TDN content of forage offered was about 45%, which would be quite low.

Table 3 Effect of selective consumption on livestock numbers and the milk production of the herd and the individual animals.

	Selection 0%		Selection 25%	
TDNR	40	45	40	45
Total milk (kg/herd/year)	3087	4996	4499	5878
No. of animals	2.2	2.2	1.7	1.6
Milk (kg/an/year)	1403	2270	2646	3673

In order to predict the effects of changes in management practices on the milk production, the following alternatives were tested:
- selection of the forage by the animal,
- urea treatment of forage.

If the animals are given opportunity for selective consumption of the roughage offered they tend to eat better quality material

(Zemmelink, 1986a; Subba Rao *et al.*, 1988; Wahed *et al.*, 1990). Selective consumption is therefore a relatively easy way to improve the quality of ingested poor quality feedstuffs, provided there is excess feed. Using this approach in the case of a large farmer and assuming 25% excess feed offered with an increase in TDN of 5 units the above process was repeated to calculate the maximum number of animals that could be kept on the farm. Table 3 shows that the total annual milk production can be maintained or even increased while reducing the number of animals. The production per animal and per herd (!) could be increased by 40% by allowing selective consumption.

If urea treatment of the entire quantity of available forage results in an assumed increase in TDN content of 5 units, the level of milk production would increase to aproximately 5000 kg/year with 2.2 animals i.e. 2300 kg per animal.

It can thus be said that both the options (i.e. allowing selective consumption or treatment of forage) available to this class of farmer enables him/her to improve the productivity of the available livestock. Selective consumption does not entail additional expenses but can be adopted especially under conditions of surplus availability of forages. In practice the decision on the optimum number of animals to be kept in this regard will also be dictated by the requirement of (working) animals which are to be recruited from replacement stock as elaborated by De Wit *et al.* (1993). Thus the same production on farm can be achieved by reduction in the number of animals (through selective consumption) or from same number of animals with equal individual production (treated forage). This point is supported by Wahed *et al.* (1990) and Zemmelink (1986b).

Case II: a small farmer (SF)

The calculations were repeated for the situation of a small farmer with a fixed number of animals, the equivalent of 1.2 milking cows. In this case the required forage dry matter was computed with a variable concentrate allowance. Table 4 indicates that with a forage of 45% TDN the predicted production that could be supported was 1800 kg per year per herd. With this TDN level in the forage the DMI of forage was predicted to be 8.1 kg/animal/day. The recorded daily DMI and annual milk production were 7.5 kg and 2100 kg respectively.

The farm grown forage available with small farmers was low (1300 kg DM per farm) which indicates that large quantities have to be brought in. Such imported forage might include road side grass, grass earned as a part of wage, or purchased forage like sugarcane tops whicn are available locally during the cane harvesting season.

In this case of limited forage supply, the selective consumption by animals can not be considered to be practical but usefulness of the treatment of roughage can be assessed. Treatment of roughage can be done to reduce the cost of production or to improve the individual productivity of the animals (see session IV of this workshop). The calculated increase in DMI of roughage after treatment was in the range of 7.5-25% depending on the assumed improvement in the TDN. Thus, with treatment the quantity of (ingested) imported forage will be higher by 13-25% as compared to the untreated forage.

Table 4 Predicted requirement for forage dry matter and milk production for a small farmer with the equivalent 1.2 milking cows.

Forage TDN	Forage DM (kg/year)	Concentrate (kg/year)	Milk (kg/year)
50	2835	711	1988
45	2444	1083	1752
40	2110	1449	1697

To compensate 5 units improvement of forage with 40% initial TDN, the extra quantity of forage needed would be 300 kg which can mean an extra expenditure of INR 150-450 per year for purchase of forage alone (assuming purchase price in the range of 0.5-1.5 INR/kg DM). Further assuming treatment cost to be about INR 130 per 1000 kg, based on local estimates (exclusive of labour costs) the total additional cost would range between INR 450-850 for the year. This additional expenditure is partially offset by the lower quantity of concentrates required. This would amount to INR 900/year in this example (INR 2.5/kg concentrate). The overall savings by treatment would thus vary between INR 50-450 per year without reduction of the annual milk production. In other words, the cost of milk production in this case is reduced by INR 0.03-0.26/kg. This figure is lower than reported by Vijayalakshmi et *al.* (1988), primarily because of the difference in the assumed price of forage and production level of the cows (see session IV). It can further be seen that at these levels of production the treatment will not be economically justified when the concentrate is cheaper than INR 1.7/kg i.e. when forage DM price is larger than approximately 0.5 concentrate DM price. This low cost of concentrate is likely to occur when farmers feed homemade concentrates like rice bran which are relatively cheap.
To improve the individual production of the animals the same quantity of concentrate (as compared to use of untreated forage) is assumed to be purchased. In this case the requirements of forage DM and milk production levels are indicated in Table 5.

Feeding the same amount of concentrate but increasing the TDN content of roughage will increase milk production. As a result, the production per animal per year was calculated to improve from 1206 kg to 1752 kg by an improvement of roughage quality from 40% to 45% TDN. The production of the animals thus increased by 40%. This compares well with the productivity improvement of 55% seen earlier in case of the large farmer when urea treated forage was offered to the animals. The case of feeding similar levels of concentrate required forage and the cost of treatment would, as seen earlier, be in the range of INR 425-625 per year while the additional milk produced is seen to be approximately 500 kg which translates into INR 1500 to 2000 per year. The additional net income (produce value minus feed cost) would thus be in the range of INR 900-1600 per year.

Table 5 Forage DM required and milk production for the small farmer with similar levels of concentrates.

Forage TDN	Forage DM (kg/year)	Concentrate (kg/year)	Milk (kg/year)
50	2722	1037	2471
45	2444	1083	1752
40	2233	1130	1206

CONCLUSIONS

The proposed formula for prediction of intake and performance of animals is used to study the management options for large and small farmers. It can indicate differences resulting from changing feeding management. In the case of large farmers the possibilities to increase production by either treatment or selective consumption could be used. The choice of those farmers was to go in for smaller number of animals of higher production or larger number of animals with lower production.

In case of the small farmer, the treatment of available forage can either reduce the cost of milk production at a given level of production increase the total producton from given level of feeds. The choice would naturally be influenced by the individual resource availability and farmer's priorities. It may be concluded that the modeling approach is sound but further work will be needed to improve the accuracy of prediction of the suggested model. No account is given (yet) for a diminishing response (in terms of milk) by increasing the supply of nutrients. The response of the animal may partly be dividing nutrients to the body resources rather than to the Mammary Gland. If the substitution rate can be predicted on the basis of indigestible matter, this become an important item for further research, in terms of validation of the assumption as well as in determining of the indigestible fraction.

The model needs to be refined and validated with the results of experiments before application on a larger scale. It may be difficult to obtain adequate data to test the validity of the results of different treatments of crop residues as only limited long term experiments have been reported.

To conclude it may be said that the model as a whole is an encouraging start and is based on the available literature (e.g. substitution rates, selective consumption, treatment effects, economics of treatment). It needs to be refined where now it produces results with non-integer numbers of animals. Also, the levels of predicted production may not be correct, but the model in this stage does help to indicate patterns of animal production related with feed quality and quantity.

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DRY MATTER INTAKE, DIGESTIBILITY AND SUPPLEMENTATION OF SLENDER AND COARSE STRAWS - A REVIEW

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SUMMARY

Dry matter intake (DMI) and digestibility studies of slender straws (e.g. rice and wheat) and coarse straws (e.g. sorghum and fingermillet) are discussed with special reference to feeding of ruminants in the tropics. The DMI varies widely within and between animal and plant species, ranging for cattle between 46-87 g per kg $W^{0.75}$ for rice straw, 40-65 g per kg $W^{0.75}$ for wheat straw and 46-81 g per kg $W^{0.75}$ for fingermillet and sorghum straws. The in vivo *dry matter digestibility is usually higher for coarse (50-60%) than for slender straws (40-55%). The TDN of slender straws ranges between 45 and 50%, with the coarse straws having comparitively higher TDN (50-62%). The cell solubles are higher in millet and sorghum straws (16-37%) than in rice and wheat straws (4-22%). Selective consumption of straws seems to depend mainly on the acceptability and other morphological and chemical characteristics of different plant parts. Strategic supplementation of straws with other feeds could improve their feeding value. At low levels of supplements in the diet, there may be an increase in straw intake and digestibility due to positive associative effects. However, at high levels of supplementation the DMI of treated and untreated straw declines due to substitution of supplements for straw. There appears to be a curvilinear effect of supplementation on intake of straw. The substitution rate is higher for treated than for untreated straws. The nutrients present and the digestibility of the supplement and also that of the basal material seems to play a major role in improving the utilisation of the basal roughage by associative effects.*

INTRODUCTION

Straws form a major but variable feed resource for livestock in India. Many different straws are available and this paper distinguishes two major groups:

- slender straws: such as rice, wheat, oats;
- coarse straws: such as millet, sorghum.

Some arguments exist to distinguish rice straw as a separate category, because it has a relatively high NDF and a low OMD (40-60%), moreover in rice straw the leaves are not always better than the stems.

Reasons for low digestibility and intake of straws in general are discussed by Singh and Oosting, 1991; Singh, Oosting and

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Tamminga, 1991; Walli *et al.*, 1993). Many methods of treatment (physical, chemical and biological) have been investigated to improve the feeding value (intake and digestion) of straws as discussed in session III, IV and V of this workshop. Urea treatment of straws and steam treatment of bagasse seem to be the most promising treatments for India. Supplementation to provide nutrients which are lacking in straw is an alternative approach to overcome nutrient deficiencies of straw. This approach is discussed later in this paper.

This paper reviews literature on the feeding values of slender and coarse straws in terms of DMI, DMD, OMD, TDN content, selective consumption and supplementation (associative effects or substitution rates due to supplementation) with other feeds. Summary data are presented in tables with reference to sources of information given in the text.

Dry matter intake

The DMI of rice straw is shown in Table 1 and varies widely in cattle (Lohani *et al.*, 1987; Ibrahim, 1985; Suryajantratong and Wilaipon, 1985; Wanapat and Uriyapongson, 1987; Borah *et al.*, 1988), in buffaloes (Wanapat *et al.*, 1984, Cheva-Isarakul and Cheva-Isarakul, 1984a, Wanapat, 1985), in sheep (Devendra, 1983a; Cheva-Isarakul and Cheva-Isarakul, 1984b; Sharif *et al.*, 1985) and in goats (Devendra, 1983a).

Table 1 DMI (g/kg $W^{0.75}$) from slender and coarse straw (mean with range).

Plant species	Animal			
	Cattle	Buffaloe	Sheep	Goats
Slender straws				
Rice	66.5 (46-87)	82.5 (60-105)	42.5 (25-60)	43.0 (40-46)
Wheat	52.5 (40-65)	40.0 (30-50)	20.0 (15-25)	27.5 (20-35)
Barley	40.5 (39-42)	- -	- -	- -
Oats	44.0 (42-46)	-	-	-
Coarse straw				
Pearl millet	-	-	51.0 (50-52)	-
Sorghum	63.5 (46-81)	66.5 (48-85)	-	-
Fingermillet	63.5 (46-81)	63.5 (44-83)	-	-

The DMI of wheat straws varies in cattle (Herrea-Seldana *et al.*, 1982; Phukan and Singh, 1983; Singh and Gupta, 1986), in buffaloes (Singh and Gupta, 1984; Singh and Gupta, 1987), in sheep (Singh and Negi, 1985; Wales *et al.*, 1990) and in goats

(Gupta *et al.*, 1988). The DMI of wheat straw was considerably less in all the animal species as compared to rice straw. Wheat straw seems to be less palatable than rice straw, whether that is due to differences in the digestibility or physical nature of the NDF fractions of these straws is not known at this stage. There is also a regional difference in preference of rice compared to wheat straw. Wheat straw is preferred over rice straw in most regions of North India but rice straw is preferred over wheat straw in for example Gujarat. The fact that farmers in northern India have a low preference to offer rice straw to their animals may be caused partially by their fear of Degnala disease (Rangnekar, 1993). Rice straw has a higher silica content than wheat straw, but the potential degradability of OM is higher in rice straw than of wheat straw. In rice straw silica is higher in leaves making them less digestible than stems (Walli *et al.*, 1988), which could also have its negative influence on palatability. This is not always true, as it is not very clear, how far silica influences the intake of rice straw as discussed below and also in Singh and Oosting (1991). The DMI for sorghum and fingermillet straws (on the basis of metabolic weight) is also variable (see Table 1), with a mean intake of 66 g/kg MW (Waghmare *et al.*, 1987; Reed *et al.*, 1988; Joshi *et al.*, 1988; Prasad *et al.*, 1990a, b). Only limited data could be found on the intake of fingermillet straw and sorghum straws for large ruminants, and no data for small ruminants. This suggests that further work to evaluate the variability in DMI of these straws is warranted.

Based on the results of cattle, DMI trials of straw from different plant species seems to decline in the following order: rice > sorghum > finger-millet > wheat > oats > barley, with only marginal differences between rice and sorghum/ fingermillet on the one hand and wheat, oats and barley straw on the other.
Despite the wide variation within species, the average DMI (g/kg $W^{0.75}$) seems to be consistent within cattle and buffaloes and between sheep and goats. Animal factors, such as age, physiological state and body size can affect forage intake and could be partly responsible for the reported variation in straw intake. However, DMI also varies between different cultivars of cereal straws and may be affected by the time of harvest, maturity and agro-climatic conditions (Nicholson, 1984; Pearce, 1985a, b; Doyle *et al.*, 1986a; Pearce *et al.*, 1988).

The differences between animal species (large and small ruminants) could be attributed to the rumen fill, rate of passage, eating time, rumination time, rate of digestion and particle size reduction, as well as on the physiological status of the animal.

Digestibility of nutrients

Dry matter digestibilities (DMD) of straws are presented in Table 2. The DMD of rice straw varies considerably in cattle (Borah *et* *al.*, 1988; Yadav and Yadav, 1989; Reddy *et al.*, 1989) and less in buffaloes (Dutta and Gupta, 1990), sheep (Saadullah *et al.*, 1981; Dolberg *et al.*, 1981; Djajanegara and Doyle, 1989; Doyle and Chanpongsang, 1990) and goats (Hadjipanayioto, 1984). However the average DMD of rice straw remains around 45 to 50 percent and seems litle influenced by species. In wheat straw the DMD varied considerably in cattle (Harrera-Saldana *et al.*, 1982; Phukan and Singh, 1983; Singh *et al.*, 1984; Yadav and Yadav, 1989). Buffaloes did not perform better than cattle (Singh and Gupta, 1985, 1987) and in sheep DMD was less variable (Singh and Negi, 1985; Wales *et al.*, 1990). The DMD of fingermillet straw in cattle was around 50-55% (Prabhu and Subba Rao, 1988; Prasad *et al.*, 1990b), and that of sorghum straw was 55-60% (Joshi *et al.*, 1988) both in cattle and buffaloes. *In vitro* DMD as low as 40% has been observed in some varieties of sorghum straw (Chairatanayuth and Wannamolee, 1987).

The DMD of coarse straws appears to be higher than the DMD of the slender straws though the DMI of the coarse straws is lower than that of slender straws. However, high variability occurs in the data. Pearce (1985) suggests that the proportion of NDS in the senescent internodes contributes to IVOMD in case of wheat and barley straw, but less in rice straw. It is generally found that amongst the slender straws, oat straw is more digestible than barley straw which is more digestible than wheat straw. The difference between slender and coarse straws may be due to lower NDF content of the coarse straws, other cell wall structures and/or degradation rates (Joshi *et al.*, 1988).

Table 2 *In vivo* DMD (%) of slender and coarse straws.

Plant species	Animals species			
	Cattle	Buffalo	Sheep	Goats
Slender straws				
Rice	47.5 (40-55)	47.0 (44-50)	42.0 (40-44)	48.0 (46-50)
Wheat	47.5 (40-55)	48.5 (42-55)	41.0 (40-42)	42.0 (40-44)
Barley	49.0 (48-50)	-	-	-
Oats	47.5 (45-50)	-	-	-
Coarse straws				
Pearl millet	-	-	54.0 (53-55)	-
Sorghum	57.5 (55-60)	55.0 (52-58)	-	-
Fingermillet	52.5 (50-55)	53.0 (50-56)	-	-

In vivo digestibility describes how the animal digests straw, but *in vitro* measures may be more practical to rank these feeds according to digestibility. For example, Wales *et al.* (1990)

reported that where IVOMD of wheat straws varied between 30 and 47%, the *in vivo* values in sheep varied only between 36 and 41%. This was shown to be due to a much longer mean retention time (over 50 hours, compared to 30 hours) of dry matter in the reticulo-rumen for the poorer quality straws (Doyle and Pandey, 1990). However, *in vivo* values or corrected *in vitro* values are necessary to compute the feeding value for ruminants.

The OMD of the slender and coarse straws is presented in Table 3. The OMD of paddy straw (Herrera Saldana *et al.*, 1982; Phukan and Singh, 1983; Singh and Gupta, 1987; Borah *et al.*, 1988; Gupta *et al.*, 1988) and of fingermillet and sorghum straw (Joshi *et al.*, 1988; Prasad *et al.*, 1990a, b) varied considerably in cattle. The OMD of rice straw in sheep was about 50% (Djajanegara and Doyle, 1989; Doyle and Chanpongsang, 1990). OMD values as high as 68.9% have been observed for rice straw in cattle (Roxas *et al.*, 1988). The OMD of wheat straw in sheep was about 43% (Wales *et al.*, 1990). In fact, it may be better to consider OMD values instead of DMD, particularly for straws which have a high ash content. Doyle and Chanpongsang (1990) show a difference of around 6 percent units between apparent DMD and OMD for rice straws in sheep. These differences will be much smaller for straws with low ash contents. The OMD values of most of the straws are low. Any successful attempt to improve the OMD values of straws will be beneficial for dairy animals because energy is one of the most limiting factors in their nutrition. The OMD values of sorghum and fingermillet straws are slightly higher (56%) than of rice straw (52%) and higher than those of wheat straw. The cell solubles are higher in fingermillet and sorghum (16-37%) than in rice and wheat straws(4-22%) (Prasad *et al.*, 1993).

It is clear that there is a wide variation in the DMI and digestibility of these straws. This may be due to varietal or environmental factors, including conditions of growth, harvesting methods and conditions and periods of storage, all of which can affect the morphological, chemical and physical characteristics of straws as discussed in the session on "variability" XX and by Doyle *et al.* (1986b), Reed *et al.* (1988), Pearce *et al.* (1988) and Subba Rao *et al.* (1989).

Table 3 OMD (%) of slender and coarse straw in cattle (average and range).

Species	OMD	
	Average	Range
Rice	52.0	(46-58)
Wheat	42.5	(40-45)
Sorghum	56.0	(50-62)
Fingermillet	56.0	(50-62)

Selective consumption of straws

Sheep and goats are probably more selective in their feed intake, than cattle. Selective consumption of crop residues may increase both intake and digestibility (Zemmelink, 1980; Kenney and Black, 1984; Wahed *et al.*, 1990). The resistance of plant material to physical breakdown can have large effects on the amounts consumed (Doyle *et al.*, 1988). In addition, selection depends more on texture and taste rather than on relative digestibility of feeds (Weston, 1985; Hogan *et al.*, 1986). Bhargava *et al.*, (1988) observed that when barley straw was fed to sheep, dry matter intake decreased in the order of leaf blades, leaf sheaths and stems. Leaf blades also had the highest potential degradability and rate of degradation. Wales *et al.*, (1990) showed that in wheat and rice straw the stems are more resistant to grinding (Table 4). In case of rice straw the stems are sometimes more and sometimes less digestible than leaves (Doyle *et al.*, 1986a). Acceptability of stems may be higher in rice straw than for leaves due to the high silica content of the leaves (Walli *et al.*, 1988). However, the effect of silica content on NDFD is not yet clearly understood. Chanpongsang (1987) and Walli *et al.* (1988) did not find any evidence that silica in rice straws affected the rate of digestion (in nylon bags). Silica may not affect digestibility per se, but may bind the microbial enzymes responsible for cell wall digestibility (Chanpongsang, 1987). These aspects are further discussed by Singh and Oosting (1991).

Table 4 Grinding energy (J/g DM) of rice and wheat straw plant parts.

Plant parts	Rice straw		Wheat straw	
	Variety 1	Variety 2	Variety 1	Variety 2
Stem	168	129	209	233
Leaf sheath	94	112	123	132
Leaf blades	84	115	90	90

Source: Doyle *et al.* (1987).

In fingermillet straw the leaf NDFD was substantially higher (51%) than the stem NDFD (33%) (Subba Rao *et al.*, 1989). These authors also observed a positive correlation for N content and stem percentage with IVOMD, and found that the level of tannins in the fingermillet straw may affect intake and digestibility. Selection for stem was observed for certain varieties of sorghum straw having higher phenolic content in leaves, especially African varieties (Joshi *et al.*, unpublished data).

The level of excess of straw offered may improve intake in cattle by giving scope for increased selection. However, digestibility with cattle has not been affected by selective intake either in treated or untreated slender straws (Badurdeen *et al.*, 1986). In the case of small ruminants, Wahed *et al.* (1990) indicated that the more digestible components of straws were selected when more was offered, and diet digestibility would be expected to increase. Some of the differences in intake observed (see Table 1), may be due to selective feeding and different experimental procedures used (Doyle *et al.*, 1986a), for instance the level of straws offered in excess of intake might have varied. Selective consumption of straw is governed by the nutrient composition of the different parts of the plant, their digestibility and probably their physical characteristics which in turn are influenced by various factors like genetic, environmental, managemental or morphological characteristics. This is discussed in depth in other papers (Subba Rao *et al.* (1989)). It may be worthwhile to identify the best parts of both cereal and millet straw for ruminant feeding which could be considered as an important characteristic to be encouraged in plant breeding programs. However, further detailed studies on this aspect are required.

Supplementation of straws

Until recently, most of the supplementary feeding studies done in India, used only one level of supplementation, without considering level of zero supplement. This does not allow an assessment of the appropriate supplement to be used for maximum utilization of the basal dietary material. A "dose response" approach is much more useful, because it provides information on:
- how each level of supplementation affects the intake and digestibility of the basal diet,
- how each level of supplementation affects production by the animals,
- economic evaluation of various feeding strategies.

Supplementation can be done in two ways:
a) for catalytic effects with low levels of limiting nutrients, e.g. for urea, branched chain fatty acids and minerals (strategic);
b) with high levels of concentrates or forages (substitutional).
Low levels of strategic supplementation has the potential for improving the utilization of the straw by providing the nutrients to support an efficient microbial growth and optimising intake and providing dietary nutrients that escape rumen fermentation and is available for absorption in the intestines.

Some of the factors which could affect the straw utilization by ruminants in relation to supplementation are :
- differences between strategic and high level supplementation;
- differences in response between untreated, treated and good quality forage for supplementation;
- quality of the supplement;
- quality of the base material and
- differences between straw species.

Supplementation with concentrate

The DMI of slender and coarse straws (untreated, urea treated) at different levels of concentrate supplementation is shown in Table 5. Similar information for forage supplements is given in Table 6. Associative effects of supplementation on digestibility of poor quality roughages and their effect on animal production have been reported (Mould *et al.*, 1983). At low levels of supplementation (10-20%), the DMI of straw can increase (Leng, 1984 a, b; Doyle *et al.*, 1986b; Saha and Gupta, 1988; Prasad *et al.*, 1990a, b). Similarly Rai *et al.* (1989) concluded with treated wheat straw that concentrate supplement of 0.89 kg/day/100 kg LW was beneficial in bringing about efficient utilization of nutrients. Trung *et al.* (1989) observed a positive associative effect of concentrate supplementation even at 0.8% DMI of live weight or 16% of dietary DM on treated rice straw intake. This effect was highest at supplementation of 0.4% DMI of live weight and declined thereafter. Concentrate supplements at 20% of the dietary DM improved DMI of finger-millet straw (Prasad *et al.*, 1990b). The level of supplement required for improved DMI of rice straw was lower than for wheat straw showing that the quality of the base material is an important factor determining the level of supplement required for positive associative effects. The substitution rate (SR) was higher with treated straw (0.55) than with untreated straw (0.42) (Creek *et al.*, 1983), indicating that the value of treating straw becomes less important as the level of supplementation increased. The SR of treated FMS was also higher (0.45) than on untreated FMS (0.12) and urea supplemented straw (0.41) (Prasad *et al.*, 1990b). Higher supplementation is required on US than TS to reach the same level of production or digestibility (Fahmy and Sundstol, 1984; Creek *et al.*, 1984; Tharmaraj *et al.*, 1989; Ghebrehiwet *et al.*, 1988). In rice as well as fingermillet straw, the total DMI was higher in the urea treated straw irrespective of the level of supplementation as compared to untreated straw (Kumar *et al.*, 1987; Prasad *et al.*, 1990b). Small amounts of specific protein supplement like fish meal did not affect the amount of straw consumed, but significantly increased live weight gain (Saadullah, 1984, 1985). In another experiment (Robinson and Stewart, 1968) a cotton seed supplement of up to 30 percent of the dietary DM did not affect rice straw intake, but it did improve production performance. This could be due to fish meal and cotton seed meal being degraded more slowly in the rumen, providing the microbes with a more constant supply of nutrients. Also, providing more energy through small amounts of specific protein supplements would help in rumen fermentation and subsequently in cellulolytic activity (Durand, 1989).

From studies (Creek *et al.*, 1983; Ghebrehiwet *et al.*, 1988; Schiere *et al.*, 1989; Prasad *et al.*, 1990b) on rice and fingermillet straw, it is observed that positive associative effects on production performance and diet digestibility are not consistent. Growth studies with urea molasses mineral block lick

Table 5 (first part) DMI and digestibility of treated and untreated slender and coarse straws at different levels of concentrate supplementations.

	Treatment 1	2	3	4	5	6
1. Saha & Gupta (1988) (dairy cattle)						
DMI (kg/day)						
urea treated paddy straw	1.63	1.50	1.79	1.52	-	-
concentrate	0.79	0.998	1.06	1.66	-	-
total	2.42	2.50	2.85	3.18	-	-
DMD (%)	59.25	52.87	55.34	57.97	-	-
OMD (%)	61.85	55.55	58.08	60.96	-	-
2. Rai et al. (1989) (Buffaloes)						
A. DMI (kg/100kg LW)						
urea ammoniated wheat straw	1.99	1.91	1.77	-	-	-
concentrate	0.47	0.75	1.06	-	-	-
total	2.46	2.66	2.83	-	-	-
DMD (%)	60.30	60.94	63.41	-	-	-
digestible organic matter intake (kg/day)	2.66	2.94	3.37	-	-	-
3. Prasad et al. (1990a) (Cattle)						
A. DMI (g/kg $W^{0.75}$)						
fingermillet straw	47.86	56.13	48.13	49.19	-	-
concentrate	0.00	14.35	28.06	28.33	-	-
total	47.87	70.48	76.19	77.52	-	-
DMD (%)	49.00	60.00	63.41	62.12	-	-
OMD (%)	51.00	63.00	67.20	64.46	-	-
B. DMI (g/kg $W^{0.75}$)						
wet fingermillet straw (1:1 moisture)	70.22	75.10	72.71	63.84	64.65	56.92
concentrate	9.24	16.85	22.06	25.12	33.28	37.23
total	79.46	91.95	94.77	88.96	97.93	94.15
DMD (%)	55.38	68.68	68.61	63.65	63.80	95.92
OMD (%)	58.65	71.28	71.30	67.96	66.04	68.46
C. DMI (g/kg $W^{0.75}$)						
4% urea ammoniated fingermillet straw	86.91	93.87	72.30	75.92	69.46	75.33
concentrate	8.80	11.71	18.68	18.98	20.71	30.69
total	95.71	105.58	90.98	94.90	90.17	106.02
DMD (%)	75.90	78.60	76.56	67.54	70.95	71.53
OMD (%)	78.93	80.30	78.58	70.29	75.33	77.26
D. DMI (g/kg $W^{0.75}$)						
2% urea supplemented fingermillet straw	67.80	62.95	61.03	53.13	46.15	63.78
concentrate	8.05	17.05	17.23	28.37	29.84	31.16
total	75.85	80.00	78.26	81.50	76.35	94.94
DMD (%)	65.05	54.70	69.59	70.74	69.15	68.35
OMD (%)	67.87	58.70	71.90	73.40	70.70	71.56
4. Prasad et al. (1990b) (Cattle)						
A. DMI (g/kg $W^{0.75}$)						
fingermillet straw	54.25	58.20	45.05	44.40	-	-
concentrate	0.00	19.07	29.80	36.98	-	-
total	54.25	77.27	74.85	81.38	-	-
DMD (%)	51.90	61.00	61.20	65.37	-	-
OMD (%)	55.05	63.40	64.05	68.45	-	-
B. DMI (g/kg $W^{0.75}$)						
2.5% urea ammoniated fingermillet straw	60.39	64.99	66.20	63.48	-	-
concentrate	0.00	15.54	27.65	29.28	-	-
total	60.39	80.53	93.85	92.76	-	-
DMD (%)	62.17	67.12	65.66	67.42	-	-
OMD (%)	64.30	69.32	68.15	70.10	-	-
C. DMI (g/kg $W^{0.75}$)						
2.5% urea supplemented fingermillet straw	68.02	68.32	60.09	58.09	-	-
concentrate	0.00	11.85	22.35	30.39	-	-
total	68.02	80.17	82.44	88.48	-	-
DMD (%)	62.00	61.50	62.13	67.74	-	-
OMD (%)	64.50	63.72	64.48	70.00	-	-

Table 5 (second part) DMI and digestibility of treated and untreated slender and coarse straws at different levels of concentrate supplementations.

	Treatment					
	1	2	3	4	5	6
5. Ghebrehiwet et al. (1988) (cattle)						
A. DMI (kg/100 kg LW/day)						
rice straw	2.30	2.10	2.00	2.20	1.90	-
rice bran	-	0.25	0.57	0.76	0.94	-
grass	0.20	0.20	0.20	0.19	0.20	-
total	2.50	2.55	2.77	3.15	3.04	-
LWG (g/day)	+120	-75	+30	+40	+50	-
B. DMI (kg/100 kg LW/day)						
urea ammoniated rice straw	2.90	2.80	2.80	2.80	2.70	-
rice bran	-	0.20	0.39	0.68	0.52	-
grass	0.18	0.16	0.17	0.17	0.21	-
total	3.08	3.16	3.36	3.65	3.43	-
LWG (g/day)	+120	+160	+220	+150	+220	-
6. Creek et al. (1983) (cattle)						
A. DMI (g/100 kg LW)						
rice straw	2.00	1.90	1.70	1.70	1.60	1.50
concentrate	0.30	0.60	0.90	1.30	1.60	1.90
total	2.30	2.50	2.70	2.90	3.20	3.30
LWG (g/day)	160	360	610	750	770	1010
B. DMI (g/100 kg LW)						
ammonia treated rice straw	2.50	2.30	2.10	2.10	1.90	1.80
concentrate	0.30	0.60	1.00	1.30	1.60	1.80
total	2.80	2.90	3.10	3.40	3.50	3.60
LWG (g/day)	620	730	780	990	1010	1170

Table 6 DMI and digestibility of rice straws at different levels of forage supplementation.

	Treatment					
	1	2	3	4	5	6
1. Tharmaraj et al. (1989) (cattle)						
A. DMI (g/kg $W^{0.75}$)						
rice straw	87.70	83.40	78.80	69.60	-	-
Glyricidia	0	8.0	16.80	35.00	-	-
total	87.70	91.40	95.60	104.60	-	-
DMD (%)	51.20	51.70	49.00	51.70	-	-
B. DMI (g/kg $W^{0.75}$) (cattle)						
ammonia treated rice straw	116.10	100.40	109.80	91.00	-	-
Glyricidia	0	8.20	14.70	31.40	-	-
total	116.10	108.60	124.50	122.40	-	-
DMD (%)	55.60	52.20	55.10	57.20	-	-
2. Suriyajantratong and Wilaipon (1985)						
A. DMI (kg/day)						
rice straw	3.02	3.21	3.32	3.37	-	-
Verano stylo	-	0.44	0.96	1.36	-	-
total	3.02	3.65	4.28	4.73	-	-
LWG (g/day)	-165	+11	+60	+104	-	-
3. Saadullah et al. (1984) (cattle)						
A. DMI (kg/100 kg LW)						
untreated rice straw	3.40	3.40	3.40	3.20	3.30	-
water hyacinth	0.20	0.20	0.20	0.10	0.20	-
fish meal	0	0.02	0.04	0.07	0.02	-
total	3.60	3.62	3.64	3.37	3.70	-
DMD (%)	58.00	60.00	61.00	61.00	62.00	-
LWG (g/day)	80	142	151	203	206	-

(UMMBL) (Leng, 1984b) and concentrate supplement (Creek *et al.*, 1984) showed almost similar responses for both urea treated and untreated rice straw (Table 5). However, at higher level of supplementation, the parallel response curves for both good quality and poor quality roughages converge. But this is because of the similarity of both rations at high levels of (concentrate) supplement (Creek *et al.*, 1984). At higher levels of supplementation, SR generally becomes positive and may not reach "one" as the supplement will definitely be more digestible than the base material. Conflicting reports on the depression of digestibility due to higher intake of straws have been cited (Khan and Davies, 1981, 1982; Badurdeen *et al.*, 1986) which could be explained through an increased rate of passage and a decreased ruminal retention time of the straw (Aerts *et al.*, 1984).

Supplementation with forages

Effect of supplementation of some forages on the intake of straw and its digestibility are presented in Table 6. Suryajantratong and Wiliapon (1985) observed a positive associative effect on the DMI of rice straw when supplemented with Verano stylo up to 30 percent of the dietary intake (see Table 5). However, Tharmaraj *et al.* (1989) observed a decline in the DMI of both treated and untreated rice straw when supplemented with low levels of *Glyricidia* (see Table 6). When relatively low levels of *Leucaena* and water hyacinth were supplemented with rice straw, there was a positive associative effect on the DMI of straw, which became negative at higher levels of supplementation. When leucena or cassava leaves comprised a significant proportion of the diet, they had little efffect on the digestibility (Devendra, 1983b; Moran *et al.*, 1983; Wongsrikeao and Wanapat, 1986). Supplementation of legume leaf plus molasses and urea tended to have only a little positive effect on growth of cross-bred cattle offered untreated or urea treated rice straw diets (Promma *et al.*, 1987). Silva and Ørskov (1988) as well as Nellovu and Buchanan Smith (1985) observed that when the straw-based diet was supplemented with relatively low levels of forage of high digestibility, there was an increase in the digestibility of the basal diet. The improvement in the digestibility of the basal feed to supplemental forage occurred when the NH_3 levels in the rumen were far below 200 mg NH_3-N/l and the supplement improved the concentration above this critical value (Leng, 1990). Perhaps the most important point from these studies is that the quality and quantity of the forage supplements influences the intake and digestibility of the base material. The supplements may be included as small amounts of the diet to provide specific nutrients depending on the situation and availability. It is possible that supplementation with forages may behave differently than supplementation with concentrates:

- due to palatability of the supplemented material,
- substitution may be on the basis of indigestible material,
- quality of the supplement.

More information along these lines needs to be generated for formulating economically viable and target oriented rations, particularly where straw forms the basal roughage and availability of concentrate supplement is limited.

CONCLUSIONS

Characteristics affecting the nutritive value of straw are low nitrogen and mineral contents, high indigestible cell wall and lignin, low rates of passage and digestion and presence of anti-nutritional factors, such as silica, oxalates and tannins. The DMI of straw shows a wide variation between and within the plant and animal species due to genetic variation and differences in cultural practices, agro-climatic conditions and morphological and chemical characteristics of the plant, but the effect may be confounded with annual effects.

Coarse straws (sorghum and fingermillet) appear to have better OMD than slender straws like rice and wheat due to higher organic cell solubles in millet straws.

Selective consumption is shown to affect intake and digestibility of straws, particularly in the case of sheep and goats which are basically selective in nature. The leaf sheath and blade of barley, wheat and fingermillet straw are more digestible than the stem portion. In rice straw, the selection for leaf is less due to the high silica content in the leaf. With cattle, increased selection occurred only when coarse straws were offered in large excesses and digestibility does not seem to be greatly affected either with slender or coarse straws.

Associative effects of supplementation on intake and digestibility of straws are yet to be clearly understood. Low levels of supplementation or strategic supplementation with concentrate or green forage can improve the DMI of the base material. High levels of supplementation tend to decrease the straw intake.

Substitution rates for treated straws become higher than for untreated straws as the potential for the intake of the basal feed increases. The chemical composition (N and the carbohydrate profile) and the physical characteristics of the supplement affects the utilization of the basal material.

Research gaps include :
- well-defined animal experiments (with descriptions of the physiological status of the animals) in order to obtain DMI values of straws grown under different agro-climatic conditions and cultural practices;
- different levels of supplementation including "O" level should be carried out to get a "dose response" effect;
- separate experiment on supplementation of concentrates and forages should be carried out as they behave differently;

- as the quality of the base material (straws) is influenced by supplementation, studies should be done with different straws and different varietals within the straw species;
- level and type of supplements needed to maximize intake and nutrient digestibility of straws should be determined with well defined dose response experiments;
- supplementation with specific nutrients for practical situations on lines consistent with modern concepts of protein and carbohydrate evaluation should be carried out to understand the associative effects;
- selective consumption of straws for cattle cannot be exploited in situation of roughage scarcity.

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SESSION THREE

BIOLOGICAL TREATMENTS

BIOLOGICAL TREATMENTS

The use of micro-organisms to improve straw quality has been considered an alternative to chemical or physical treatments and supplementation of straw basal diets. One fungus is known to improve quality of lignocellulosic materials (wood!) in nature, the famous case of "palo podrido". Nevertheless, up till to date no successful straw treatment with micro-organisms is known that can be applied under farmers conditions.

A large variety of treatments has however been developed for experimental conditions, including the two stage Karnal process. They are reviewed with many practical drawbacks and potentials, in the paper of Gupta et al. Many of these socalled biological treatments require some kind of chemical/physical pretreatment and each of these processes has different objectives, which are often not well defined and research into this issue often lacks a clear objective. The processes can aim at one or more of the following aspects of straw nutritive quality: increased digestibility, increased intake and/or increased protein content. The real mechanisms that govern straw digestibility are complex and not yet sufficiently understood. Lignin content alone does not explain digestibility or intake sufficiently, and (the degree of) lignin-hemicellulose bonding might also be responsible for poor nutritive quality of biologically treated straws. Moreover, straw can also be used for production of other (bio)chemical products as reviewed by Neelakantan and Deodhar.

Nutritive quality in terms of energy can also be considered to be the potential intake of digestible organic matter (DOMI). Therefore, a decrease in digestibility can be compensated by an increase in intake. The inevitable organic matter losses during biological treatments even cause a decrease of organic matter content, more so in high ash substrates (e.g. rice straw), than in low ash substrates (e.g. bagasse). This implies that an increased organic matter digestibility is needed to compensate for the loss of organic matter content. These issues are discussed in the paper by Rai et al.

A discussion of protein (quality) aspects of biological treatment is given by Walli et al. *Protein content (measured as N * 6.25) can increase relatively due to organic matter losses, even when absolute protein losses occur. But with feeds such as straws, energy is likely to be equally or more limiting than protein, i.e. the usefulness of increasing protein is often limited. Moreover, protein can be added by non-protein-nitrogen (NPN) supplementation, though the fungus of the Karnal process (see Gupta* et al.*) seems to be able to convert NPN compounds into protein. The Karnal process uses fungus (Coprinus) that tolerates ammonia compounds, though normally ammonia acts as a fungicide (see Kishan Singh* et al.*).*

Major practical problems of biological treatments in solid state fermentation (SSF) that remain are:
- *difficulties in process control of the SSF, i.e. the oxygen-, carbondioxide- and temperature gradients vary largely in the*

stack, giving rise to unwanted growth of contaminant organisms,

- *organic matter losses can be reduced but are inevitable since fermention requires at least some (in)soluble carbohydrates,*
- *no micro-organism has been identified that significantly improves one or more of the straw quality parameters and that manages to survive in SSF at farmers conditions,*
- *growth of contaminant organisms is difficult to prevent entirely, hence care needs to be taken to avoid short and long term toxicological aspects.*

Given the theoretical and practical problems, the future work on microbial treatment requires:

- *better microbiological/biochemical understanding of basic processes,*
- *better definition of the goals of treatment in terms of protein quality, digestibility, organic matter losses and intake,*
- *recognition of differences between organisms and substrates, and consideration of the possibilities of mixed cultures,*
- *good assessment of costs and gains expected in terms of improved nutritive value.*

BIOLOGICAL TREATMENT - RECOMMENDATIONS

The results of the fungal treatment of ammoniated straws have shown that the process is consistently accompanied by organic matter losses, reduced digestibility, increased (D)CP and reduced TDN in the fermented product causing a net loss of nutrients. Further work on solid state fermentation, genetical improvement of microbes, or on scaling up of the process should be done by microbiologists, biochemists or bioengineers, before the nutritionists can continue to test a process for field application.

The possible use of white rot fungi in bioconversion can be taken up in the following respects:

(i) selection and improvements of strains,
(ii) substrate pretreatment to favour growth of particular organisms,
(iii) interaction between indigenous microflora and the added inoculum of white rot fungus, i.e. use of mixed cultures,
(iv) scaling up of the process and control of solid state fermentation,
(v) only if there is success in above (i) to (iv), should nutritional evaluation of the product be taken up.

Easy and rapid methods of biomass estimation have to be explored to assess the amount of microbial biomass in the product.

Potential (accute and long term) toxicity of the degration products and fungal cultures requires attention of the researchers.

Systematic studies are required on the process control and economic feasibility of the process, before deciding research priorities. The objectives of future research need to be well defined such as use of enzymes, production of microbial protein or increase of intake.

The use of probiotics can be explored for improved feed conversion by animals.

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BIOLOGICAL TREATMENT OF LIGNO-CELLULOSICS AS FEED FOR ANIMALS AN OVERVIEW

B.N. Gupta[1], G.P. Singh[1] and Kishan Singh[2]

SUMMARY

A vast energy potential for animal feed is locked in the ligno-cellulosic materials. Physical and chemical treatments are known to improve feed quality, and recently attention is drawn to biological treatments that increase the feeding value. Such biological treatments include the production of single cell protein from ligno-cellulosic wastes, use of straw left after mushroom production and the use of enzymes. Fermentation of plant biomass for conservation as is done with existing methods of ensiling is a fundamentally different concept than biological treatment to obtain a better feed. Problems with cultivation of fungi on straws include losses of organic matter and other nutrients, and attempts were made to isolate the specific enzymes responsible for positive effects of biological treatment so that these could be used directly. This paper summarizes all those approaches and a recently developed Karnal Process using a two stage technique which improved CP content of cereal straws with limited organic matter losses.

INTRODUCTION

Ligno-cellulosics are the most commonly and abundantly available organic compounds in nature. In contrast to this, the enzymes required for their breakdown have a limited distribution and are mainly confined to micro-organisms. Vertebrate animals depend on microflora inhabiting the rumen and caecum for digestion of cellulosic materials. The digestion of ligno-cellulosics is low because of the presence of lignin, physico-chemical bonding between polysaccharides like cellulose and hemicellulose or suboptimal functioning of the rumen of animals fed on such feeds. (Sundstøl and Owen, 1984; Singh and Oosting, 1993; Singh et *al.*, 1993).

A considerable part of photosynthetic activity in plants is used for the conversion of atmospheric CO_2 to these ligno-cellulosics. A vast energy potential is, therefore, locked in these ligno-cellulosic materials. To improve the access of hydrolytic enzymes to cellulose and hemicellulose, it is necessary to disrupt the organization of the ligno-cellulosic or ligno-hemicellulosic bonds of the plant cell walls (Fan et *al.*, 1982).

Though the required enzymes for breakdown of ligno cellulosics are mainly produced by micro-organisms, the decay of ligno-

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cellulosic materials is a normal phenomenon in nature and accomplished by organisms which mostly function through decomposition of various components of these materials. Fungi play a role in these processes, and they can be divided in groups, i.e.:

- brown rot fungi that preferentially attack the cellulose and hemicellulose, which are essentially fed to ruminants as an energy source, and leave behind a brown residue,
- soft rot fungi like *Chaetomium cellulolyticum*, that leave the attacked lignocellulosic material watery soft at the surface layer and that break down the lignin as well as cellulose and hemicellulose,
- white-rot fungi that are capable of breaking down the lignin without much attacking the cellulose and hemicellulose

(Agosin and Odier, 1985; Zadrazil, 1984).

A white rot fungus like *Phanerochaete chrysosporium* degrades lignin to the extent of 65-70% while other fungi like *Ganoderma applanatum* and *Coriolus versicolor* degrade over 45% of lignin in the lignocellulosic materials. The conversion of straw into a better quality feed by delignification through white rot fungi in semi-solid cultures aims at maximum lignin biodegradation with minimal degradation of cellulose and hemicellulose (Agosin *et al.*, 1986), as further elaborated by Rai *et al.* (1993). Thus, the use of white rot fungi or other organisms on straws could be an alternative to chemical and physical treatments to enhance the straw quality for animal feed (Zadrazil and Brunnert, 1981). Others argue that it is not the lignin that needs to be attacked but the bonds between lignin and hemicellulose. Also, it could be possible to find a mix of micro-organisms rather than a pure culture that improves straw quality.
This paper first briefly discusses (bio)chemical backgrounds and secondly it reviews microbiological processes used for upgrading straw quality. The emphasis is on biological methods to increase straw quality, not fermentative processes for conservation of feeds such as silages.

BIODEGRADATION OF LIGNIN

Lignin biodegradation is largely an oxidative process. In aerobic environments, lignin peroxidases break the lignin polymer into products which finally can be converted to CO_2. The white rot fungus *Phanerochaete chrysosporium* has shown the highest ligninase activity in the presence of glycerol as carbon source and asparagine and ammonium salts as N sources (Glenn *et al.*, 1983; Tien and Kirk, 1983; Kirk and Farrel, 1987). Lignin peroxidase (diaryl propane oxygenase) is an H_2O_2 dependent lignin degrading enzyme which catalyses the oxidation of various lignin model compounds (Kuila *et al.*, 1985). Isolated systems do not depolymerize lignin, but the lignin-peroxidase system occurs in lignin peroxidase-catalyzed oxidation of lignin. When lignin-peroxidases enzymes are added to active fungal cultures the degradation of lignin is enhanced. This means that the fungus has a mechanism to change the tendency for spontaneous polymerization to degradation. Using *P. chrysosporium*, key reactions in lignin biodegradation, such as aromatic ring cleavage, quinone formation, acid formation and the role of oxygen in lignin peroxidase catalyzed reactions, were studied (Schmidt *et al.*, 1989). During the oxidation of lignin peroxidase active mediators, 1 atom of dioxygen is incorporated into the product. It has now been indicated that the enzyme ligninase contains a haemporphyrin which is oxidized by H_2O_2 to become a powerful oxidizing agent, capable of drawing electrons out of the phenolic rings in lignin thereby breaking apart the polymer (Harvey *et al.*, 1986). The major step after oxidation by lignin peroxidase is reduction of the resultant products to CO_2 by *P. chrysosporium* (Leisola *et al.*, 1988) and the optimum pH for this reaction is suggested to be 3. Another enzyme laccase, a copper dependent enzyme, found in many lignin degrading organisms is thought to be active in oxidation of the phenolic structure in lignin (Kawai *et al.*, 1988). More recent information on the biochemical processes is given by Neelakantan and Sondhi (1988), Coughlan (1989) and Odier (1987).

MICROBIOLOGICAL PROCESSES THAT UPGRADE STRAW QUALITY

Various attempts have been made to improve straw quality for animal feeding, or to use by-products of microbial processes on straw as animal feed. It is essential to remember that these processes have divergent goals, ranging from production of single cell protein for monogastric nutrition, via use of spent straw after mushroom production to increase of digestible energy value of straw. Some processes are listed in Table 1, and a few are described below in greater detail. Use of straw and biochemical processes for non-feed production are discussed by Neelakantan and Deodhar (1993).

Table 1. Summary of biological processes to use or improve straw for animal feed.

Major aim	References
Microbial Biomass protein (MBP)[1]	Han, 1978; Moo-Young, 1979; Chahal and Moo-Young, 1981
Use of mushroom spent straw for feed	Zadrazil, 1980; Langar, 1982; Zakia Bano, 1988
Enzymes	Harvey et al., 1987; Buswell and Odier, 1987
Ligno(cellulolytic) micro-organisms 1986 to increase digestibility	Langar, 1982; Kamra and Zadrazil, 1986; Zadrazil,
Improved protein value (Karnal process)	Gupta, 1988

[1] previously called single cell protein

Single cell protein production from ligno-cellulosic wastes

Han and co-workers (Han, 1978; Han *et al.*, 1975) developed a fermentation process essentially involving growth of micro-organisms other than fungi on straw in solid state fermentation (SSF). Since straw is normally resistant to microbial growth, pre-treatment was done before yeast cultivation. There are two processes:

- in the first process, the straw is hydrolyzed with 3 parts of 0.5 N H_2SO_4 and 1 part of the straw which is steam treated in a pressure cooker under 10-15 psi of steam pressure for 30 minutes. The acid hydrolyzed straw is then treated with NH_3 to raise the pH to 4.5 and it has been estimated that at this stage it contains 20% fermentable sugars and 2.3% N. This is then incubated with suitable organisms like *Candida utilis* or *Aspergillus pullulans*.
- in the second process, straw is treated with 4% (dry weight) NaOH and after neutralisation of excess alkali, an N source such as ammonium sulphate is added. This pretreated straw is then inoculated with the cellulolytic organisms like mixed cultures of cellulomonas sp. or *Alcalegenes faecalis*.

In both the processes, the fermentation chamber is maintained at a constant temperature and humidity with constant tumbling motion to permit exchange of air. The basic advantage of this solid state fermentation is that the absorptive properties of the straw are utilized, to provide a substrate in optimum conditions for fermentation. In the pre-treatment step, the portion of the straw, which is not dissolved, retains its fibrous nature and acts as a matrix to hold water, soluble carbohydrates and other added nutrients. Moreover, all these components are held in a semi-solid mass so that fermentation can proceed in a simple manner by tumbling in presence of air (or by blowing air) whereby the equipments and controls needed in submerged fermentation are avoided.

However, although the fermentation increased the protein content and the *in vitro* rumen digestibility (IVRD), the feeding experiment was conducted only on the meadow voles (*Microtus canicandus*) as the quantity obtained through SSF was small. The experimental voles responded very poorly to the fermented straw. Feed intake was low, animals showed an unkempt appearance and gained little weight. The feed efficiency was even lower than that of the untreated straw. The possible adverse effects were believed to be due to harmful products formed during acid hydrolysis or high levels of ammonia and/or sulphur. The inhibitory effect of lignin degradation by-products on gut microflora, or oxidation of phenol derivatives to quinone which may aggregate with plant proteins and other cell wall components were possible factors that reduced the digestibility or inactivated the digestive enzymes in the gut (Han *et al.*, 1975).

Waterloo process

The Waterloo Single Cell Protein process as developed by Moo-Young and *et al.*(1981) is based on the initial treatment of straw with alkali at high temperature and subsequent inoculation with the soft rot fungus *Chaetomium cellulolyticum*. The dispersion of mycelium with cellulose facilitates the organism to utilize cellulose and sugars like xylose and mannose derived from the hydrolysis of hemicellulose. Because of environmental pollution and problems of toxin production on cellulosic wastes, the straw substrate was later replaced by either glucose or molasses. However, time of harvest and the nature of substrate had a large influence on the microbial biomass protein composition and nutritive evaluation (Chavez et *al.*, 1988a). The amino acid profiles of the two fungal samples produced on glucose and molasses substrates compared relatively well with that of dried skim milk although the total amino acid analyzed were lower than the dried skim milk. Usually, the amount of nucleic acid reportedly present in this kind of Microbial Biomass Protein (MBP) was relatively small (Moo-Young *et al.*, 1979) which seemed to be due to contaminant NPN. MBP samples were freeze dried at -25°C and when supplemented with 0.4% DL-methionine showed significant responses in body weight gain, feed consumption and feed to gain ratios among rats (Chavez et *al.*, 1988b). The absolute nutritive value and acceptability of the cellulolytic fungus as MBP varied not only with the substrate provided for fungal growth, but also with the production process. In a practical diet for weaning pigs and chicks, the fungal MBP grown on molasses replaced 50% of the dietary protein supplied by soybean meal with excellent results (Chavez *et al.*, 1988c).

The 'palo podrido'

In South Chile, fungal delignification of wood has been observed under natural conditions. The product after delignification viz. 'palo podrido' is used as animal feed which is a white decomposed wood (Zadrazil, 1984). The fungus responsible for the degradation of wood belonged either to *Ganoderma applanatum* or *Arnillariella* sp. However, some of the fungi like *Phanerochaete chrysosporium* degrade hemicellulose, cellulose and lignin non-selectively which adversely affects the digestibility of cell walls of the product in the rumen (Agosin *et al.*, 1986). Zadrazil *et al.* (1980) steam treated wheat straw, inoculated it with white rot fungus like *Dichomitus squalens* and incubated for 6 weeks. No nitrogen source was used in this process. There was a marginal increase in N content of the treated straw which was mainly due to carbon loss during the incubation period. However, the lignin content decreased and the digestibility of wheat straw improved. The optimum pH during fermentation was 3.

Mushroom production and the utilization of spent straws as cattle feed

Many Asian families grow edible mushrooms, often using cereal straw as the partial or complete growth medium. Sawdust can also be used (Flegel, 1987). In a study by Zadrazil, the use of large used plastic fertilizer bags was suggested as these could be stuffed with the straw and then steamed as such. After cooling, the bags could also be inoculated with the white rot fungus (*Pleurotus* sp.) and incubated for several weeks. When the bags had been filled with mycelium, they were slit open at the top which allowed fruiting, from which often could be harvested. The residual straw after the harvest of mushroom could be fed to ruminant animals. Similar work is reported by Zakia Bano and Raja Rathnam (1988) for *Pleurotus* and by Basuki (1987) for *Volvariella* as discussed later. Zadrazil and Brunnert (1981) confirmed that at lower temperatures *Ganoderma applanatum* preferentially degrades lignin in wheat straw and helps increase the digestibility of the fermented product.

Volvariella volvacea is the common mushroom grown on paddy straw in China and other countries (Basuki, 1987). Pre-treatment of straws by cutting and spawning facilitates *V. volvacea* to colonise the straw substrate quickly. *Coprinus fimetarius* has also been shown to grow quite easily on straw bales impregnated with a solution of calcium nitrate or a mixture of limestone and ammonium nitrate in solution. The chemical treatment is simply achieved by dipping straw bales in the hot solution at 80°C. On cooling to 40°C, the bales are inoculated with *C. fimetarius* and a relative humidity of above 90% is maintained in the environment. Fruiting bodies appear within 5-10 days (Smith *et al.*, 1986).

Zakia Bano and Raja Rathnam (1988) utilized the *Pleurotus* sp. for conversion of plant wastes into food. *Pleurotus* sp. (Oyster mushrooms) cultivated on cereal straw converted the straw into edible biomass leaving behind the degraded spent substrate. Conversion of ligno-cellulosic wastes into edible fruit bodies was high with *Pleurotus* sp. and the protein conversion efficiency with this species was also high. The inoculation with *Pleurotus* sp. produced out of 100 kg original biomass 11 kg of fruiting bodies and 26.5 kg as spent straw, and the remaining accounted for by loss in the form of CO_2 and water. These workers have also suggested that the spent straw in its degraded form could be used for ruminant feeding.

However, when the spent straw from mushroom (Agaricus) cultivation was fed to ruminants. Langar *et al.* (1982) found that the digestibilities of OM, NDF and cellulose were significantly ($P < 0.01$) lower than those observed for untreated wheat straw. However, the DCP was 0.80% in spent straw against nil in untreated wheat straw, probably caused by a higher total N-content (Sampath *et al.*, 1993). These workers further observed that the complete replacement of wheat straw with spent straw was unacceptable to buffaloes even when a soluble carbohydrate source like molasses was added. By and large, the chemical composition and digestibility of the spent straw invariably were lower than those observed on the untreated wheat straw. Unlike *Pleurotus*, Agaricus spent substrate had poor acceptability probably due partly to different (composting) processes. Even after removal of the soil casing, the high ash content and gypsum residues left after straw composting for Agaricus production resulted in low acceptability (Langar *et al.*, 1980). However, washed Agaricus spent substrate was observed to be more acceptable than unwashed spent substrate. Washed Agaricus spent straw had 6.8 and 55 percent DCP and TDN respectively. When supplemented in the wheat straw ration, replacing 40% of the concentrate mixture with washed spent straw supplemented as pellets, Bakshi and Langer (1985) confirmed the availability of N from Agaricus washed spent straw.

The best edible fungi which give good yield of fruiting bodies and showed an increase in *in vitro* digestibility are *Pleurotus* spp. and *Stropharia rugosuannulata*. The increases in the *in vitro* digestibility of straw were from 60 to 65% and from 40 to 72%, respectively (Zadrazil, 1986).

Whole substrate feeding

Reid (1985) developed a process by using aspen wood and the fungus *Phlebia tremellosus* which selectively removes the lignin from soft wood as well as hardwood. The solid state fermentation in this procedure could be carried out in deep static layers under optimal pH range of 4-6. Interestingly, no nutrients were required to be added to the wood shavings. Both, simple and complex N supplements were inhibitory to the process of delignification. Within 8 weeks, this fungus removed 52% of lignin and the total wood weight loss was only 12%. The cellulose digestibility in this biologically delignified material increased from 18 to 53% as determined by *in vitro* method.

McQueen and Reade (1981 - 1982) fermented 5 kg of poplar saw dust with 10 litres of sterile mineral solution and added inoculum of 4 weeks old liquid culture of white rot fungus *Ganoderma applanatum*. After 4 weeks of fermentation, the product was found to contain cellulose 51%, hemicellulose 19%, lignin 9% and CP 2.6%. The intake and digestibility of the whole substrate was equivalent to low quality timothy hay. Reade and McQueen (1983) observed that the *in vitro* rumen digestibility (IVRD) of whole substrate of poplar shavings varied with type of inoculum used. Inoculation with *Polyporus anceps* increased IVRD from a control value of 30% to 72% after 8 weeks of fermentation, but it was 64% with *Ganoderma applanatum*, 62% with *Phanerochaete chrysosporium*, 61% with *Polyporus versicolor*, and 42% with *Fomitopsis ulmarius* after only 4 weeks of fermentation.

Basuki (unpublished, 1985) made improvements in the SSF process. Pre-treating of straw was done by soaking in water overnight and then mixing the straw with rice bran and lime stone in the proportion of 50 : 5 : 2. The whole mass was then composted for 6 days giving a turning on day 3 but the stack was kept covered with polythene sheet. On day 7, it was inoculated with *Coprinus cinereus* spawn and again covered with plastic sheet for another 6 days. The CP content increased from 4.65% in the untreated rice straw to 9.36% in the fungal treated straw. The feeding experiments on growing cattle for 90 days, however, showed negative growth rates. Also, the DMI of fungally treated straw was lower than of untreated straw.

The digestibility of ruminant feed, when improved by cultivating *Pleurotus ostreatus* and *Lentinus edodes*, is related to the solubilization of the structural polymers of the substrate. A statistically highly significant ($P < 0.01$) relationship between rumen digestibility, soluble sugar and soluble lignocellulosic complex contents was observed. From the biological point of view, this correlation suggests that improvement of digestibility is due to the concomitant degradation of the three main types of structural macro molecules, thereby increasing the availability of the carbohydrate fraction (Giovannozzi-Sermanni *et al.*, 1989). Other workers also observed improvement of digestibility of wheat straw using *Dichomitus squalens* (Agosin and Odier, 1985; Zadrazil and Bunnert, 1982) and *Cyathus stercoreus* (Wicklow *et al.*, 1980). These two fungi facilitated improvement of *in vitro* dry matter digestibility (IVDMD) of wheat straw after 20 days cultivation with 15-20% dry matter loss. A good correlation was found between lignin degradation and digestibility while phenolic acid decrease showed no correlation with digestibility of decayed straw. Water-soluble substances consisting of soluble sugars as well as of lignin degradation products increased in decayed straw. The extent of digestion of cellulose and xylan was increased to various degrees depending on the fungal strain. Improvement of digestibility of decayed straw seemed to result from both solubilization as well as increased biodegradability of cellulose and xylan in straws (Agosin *et al.*, 1986).

Flegel and Meevootisom (1986) did not succeed in biological treatments of rice straw until it was preceded by pre-treatment either by heating or steaming. Later some success was, however, achieved with *Coprinus* sp. which is a common inhabitant of rotting straw in which case pre-treatment was avoided before its incubation. But they suggested that while carrying out the SSF using the straw without any pretreatment, the problems of contamination by unwanted fungi could be avoided either at a very low or at a high pH (Flegel, 1988). To avoid unwanted fungal growth and to elevate pH, urea was used for dual purposes, i.e. as N source and also to maintain a high pH which did not harm the *Coprinus* sp. while the other fungal competitors were eliminated to a large extent. Another benefit with *Coprinus* sp. was its non-toxicity. Unfortunately, field trial with *Coprinus* sp. treated rice straw showed negative growth rate in cattle on 90 days feeding. The feeding trial with goats on fresh straw was largely unsuccessful (Flegel and Meevootisom, 1986).

THE KARNAL PROCESS

The Karnal process as conceived and developed by Gupta (1988), is essentially a biological treatment of lignocellulosics in an SSF under non-sterile conditions. The Karnal process consists of two stages:

- in the first stage, lignocellulosic materials like cereal straws are treated with 4% urea keeping the moisture level at 40%, and keeping the straw stack enclosed in cemented silo pits or under polythene cover for 30 days.
- in the second stage, a temporary loose brick structure of rectangular shape (2 x 1.8 meter) is prepared in such a manner that aeration from all sides is ensured. In this brick structure a thin layer of urea treated straw is spread evenly and thereafter urea treated straw is taken in lots of 10 kg (6 kg on DM basis) and mixed thoroughly with 60 g single superphosphate and 6 g CaO (1% SSP and 0.1% CaO on DM basis) dissolved in about 8 litres of water. This moisturized and mineralised material is then evenly spread inside the brick enclosure over the earlier thin layer of urea treated straw and inoculated with 3% of *Coprinus fimetarius* culture grown on millet seeds taking care of even casting on the material. To allow sufficient aeration as well as dissipation of heat which develops during the SSF, several specially designed perforated vents (30 cm h x 15 cm dia) are placed evenly at short distances which help to maintain the temperature of fungal treated straw during SSF between 35-42°C. This exercise is done layer by layer till the brick enclosure is filled. The entire enclosure is then covered with empty bags or black polythene sheets. Prolific growth of fungus can be observed by 5th day.

The major advantage of the Karnal process is that in the second stage the *Coprinus fimetarius* captures nitrogen compounds that were generated by urea in the first stage of treatment. The higher amino acid content of the fungal treated straw compared with untreated or urea treated straw suggests that the N-compound capture by *C. fimetarius* is mainly utilized for the synthesis of amino acids for formation of fungal proteins during mycelial growth (Gupta, 1988; Walli *et al.*, 1993; Kishan Singh *et al.*, 1993). The DM losses due to fungal growth during 5 days was only 7-10% and the CP content increased to 13-14%. The total period for fungal treatment of cereal straws through two stage Karnal process as originally developed was stipulated to be 35 days (first stage: 30 days for urea treatment + second stage: 5 days for SSF). Recently some experiments were conducted to reduce this total period of the Karnal Process for large scale industrial production of fungal treated straws. Thus, instead of using urea for treatment of straw in the first stage of the Karnal process, the anhydrous NH_3 was used. This 3% anhydrous ammonia treated wheat straw (for 7 days) was later inoculated with *Coprinus fimetarius* fungus after due mineralization and moisturization as earlier. It was observed that profuse fungal growth was obtained within 5 days as it was obtained earlier with urea treated straws. The fungal treated wheat straw so produced was in no way different than that produced by using urea treatment in the first stage before. With this modification the total treatment time has now been reduced to barely 12 days (First stage: 7 days for 3% anhydrous NH_3 treatment + second stage: 5 days for SSF). It is envisaged that it is possible to reduce further the SSF period from 5 days to barely 3 days by devising a tray type incubator having controlled moisture, temperature and moderate aeration facilities. This type of incubator will reduce the lag time by bringing the SSF temperature rapidly to 37°C after fungal inoculation and will also maintain it between 37-42°C during SSF which is a conducive temperature range for rapid mycelial growth of *Coprinus fimetarius*. This will in turn reduce the DM losses further and reduce the level of microbial contaminants. It also makes the process more industrial in nature as is the case with many other biological treatments.

Pretreatment with enzymes

Knowledge of the type of enzymes produced by micro-organisms that grow on lignocellulosic substrates is of considerable value in designing procedures to modify or improve processes that use these fungi. Such microbial processes include the production of edible fungi (mushrooms), animal feed, enzymes, paper industry waste processing and other possible by-products. For cellulose and hemicellulose biodegradation in the nature and properties of the extra-cellular enzyme systems produced by these fungi are well characterised. The enzymes include various cellulases, oxidases, hemicellulases and glycosidases (Harvey *et al.*, 1987; Bushwell and Odier, 1987; Wood and Kellog, 1988; McDonald *et al.*, 1991).

When the cellulases obtained from the fungus *Trichoderma viride* (Henderson *et al.*, 1982) was used for treatment of the straw, the increase in cellulose digestibility over the untreated straw was non-significant. However, the digestibility increased two fold when the enzyme treatment was followed by the alkali treatment, though it is not sure that the enzyme was necessary to obtain such an increase. This was because the enzymes were not capable of penetrating the bonds between cellulose or hemicellulose and lignin (Klopfenstein, 1978). The situation of lignin biodegradation is currently less clear. Many basidiomycete fungi possess active lignolytic systems when tested with whole cultures growing on native ligno celluloses or with synthetic lignin. At least *Phanerochaete chrysosporium* has a defined lignin degrading enzyme, a ligno peroxidase, which has been isolated and also characterized. White-rot fungus *Pleurotus* reduced lignin content by 65% (Klason method) in 3 weeks during mushroom production on cotton straw (Platt *et al.*, 1981) as well as on wheat straw

(Bakshi and Langar, 1985). Although lignin is generally considered to be indigestible by ruminants, some observations in lambs have suggested that lignin can be degraded by rumen microflora (Muntifering *et al.*, 1981). Akin (1980) isolated a filamentous facultative anaerobic micro-organism from rumen fluid that could attack lignified plant tissues. According to Zeikus (1981), fungi must degrade lignin either to gain access to the polysaccharide of the wood or for its own survival but not for growth. Whether lignin is degraded via low molecular weight aromatic products or by the cleavage of the aromatic nuclei still bound to the polymer, is not clear. Others opine that on degradation of lignin, the intermediate products produced have a negative effect on rumen microflora (Han *et al.*, 1975).

CONCLUSIONS

A large variety of biological treatments are tried on lignocellulosic materials. The methods differ in substrate (type of straw), type of fermentation and purpose of treatment. Not many methods are actually applied in practice and many require industrial approaches. The major problems are those of solid state fermentation, organic matter losses, isolation of proper organisms, and risks of toxicity, though the latter is not elaborated in this paper. The unique feature of the Karnal process is that it appears to incorporate the capture of free nitrogen compounds. Recent improvements of the Karnal process include the reduction of time required.

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A MODEL TO OPTIMIZE ENERGY INTAKE OF RUMINANTS FROM BIOLOGICALLY TREATED CROP RESIDUES

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SUMMARY

The treatment of lignocellulosic crop residues by using fungi and its potential to enhance digestible energy intake by ruminant animals is discussed in order to prioritize further research. Losses of organic matter during solid state fermentation are inevitable and can reduce the energy content of fermented crop residues even when organic matter digestibility increases. This paper describes a conceptual model to optimize biological treatments of lignocellulosics and highlights the effect of treatment over time on the feeding value of fermented materials. Feeding value is defined as potential digestible organic matter intake, i.e. product of organic matter content, organic matter digestibility and intake. Two very different crop residues, i.e. rice straw and bagasse, and two sets of fermentation conditions, namely slow and fast growing, have been considered as case studies. It is concluded that organic matter losses are more serious with rice straw than with bagasse because of the higher ash content in rice straw. Also, it may be necessary to accept organic matter losses to achieve higher digestible organic matter intakes, when intake over time increases faster than the decrease in digestibility.

INTRODUCTION

Interest has been shown in recent years in the use of biological treatment procedures to improve nutritive quality of straws by adopting fungi in solid state fermentation systems (SSF) (Domsch *et al.*, 1981; Zadrazil and Brunnert, 1982; Agosin and Odier, 1985; Van der Meer *et al.*, 1986; Basuki and Wiryasasmita, 1987; Walli *et al.*, 1987; Gupta, 1988; Rai *et al.*, 1988; Singh *et al.*, 1989; Singh et *al.*, 1990 a, b; Singh, 1993). Fungi differ in their ability to alter the digestibility of lignocellulosics for ruminants. Few fungi have a positive effect, whereas most others show an adverse effect on the digestibility often depending on whether they are white rot, soft rot or brown rot fungi (Zadrazil, 1984; Kamra and Singh, 1987). Species such as *Stropharia rugosoannulata*, *Pleurotus* spp. and *Abotiporus biennis* S. can increase the *in vitro* digestibility of straw up to 30% (Kamra and Zadrazil, 1988; Badve *et al.*, 1987), whereas Rai et *al.* (1987), using fermented straw with *Coprinus fimetarius* as sole diet in goats, reported that *in vivo* digestibility of different nutrients either declined or remained equal with the

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control. They further indicated that the digestibility of fermented straw largely depends on OM losses during SSF. Most trials study only the effect of treatment on digestibility, but the nutritive quality is a combination of at least three factors: OMD, OM content and DMI. The effect of treatment on each of these factors is determined by the nature and duration of the treatment, the micro-organism and the original substrate. This paper discusses the relative importance of these aspects and their interrelation, in order to set priorities for further work. Other aspects of nutritive quality include the protein content and quality (Walli *et al.*, 1993; Gupta, 1988), and toxicity (Deodhar and Gupta, 1988) and are not discussed in this paper.

FACTORS AFFECTING SOLID STATE FERMENTATION AND THEREFORE NUTRITIVE VALUE

Amongst different processes, SSF is probably the most economical and practical method for large scale fermentation of biomass with micro-organisms. SSF is a process where an insoluble substrate is fermented with sufficient moisture but without free water. Changes in solid state fermentation affect the rate and species of microbial growth, as well as the quality of the final product. Following are few of major factors affecting SSF (Weiland, 1988).

Moisture content

The optimum moisture level in SSF depends on the nature of the substrate, the organism and the type of the end product required. Ranges from 50-75% moisture have been reported as being optimal for various products in SSF carried out in the laboratory. A high moisture content of the SSF results in decreased porosity, gas exchange, oxygen diffusion, gas volume, but increased risk of bacterial contamination and enhanced formation of aerial mycelium. On the other hand, lower moisture levels lead to sub-optimal growth and less swelling of substrate. The moisture content of the substrate continues to change during the fermentation due to evaporation and metabolic activities. The maintenance of moisture content during fermentation depends on air circulation relative humidity, stack size etc.

Temperature

Temperature affects the rate of biochemical reactions during the fermentation process. Due to the heat produced during fermentation and because of the poor conducting properties of the substrate (crop residues), a rise in temperature is common. Differences between ambient and fermentation temperature should be recognised.

Exchange of gasses

Gas exchange between gaseous phase and solid substrate affects the process of fermentation. The gradients of oxygen and carbon dioxide concentration determine respiration rates, rates of biological activities and biological state of the system. Gas exchange is affected by the moisture content of the substrate. Excessive water hinders the exchange of gases and creates anaerobic conditions inside the substrate whereas insufficient water does not permit optimal fungal activity. The optimum level of solid : liquid ratio in solid state fermentation depends on substrate quality, particle size, water holding capacity of substrate and type of desired micro-organism (Zadrazil and Brunnert, 1981; Flegel and Meevootisom, 1986; Kamra and Zadrazil, 1987).

THE MODEL AND AIMS OF THE BIOLOGICAL TREATMENT

The prime aim of the many experiments with biological treatment of crop residues is often not well stated, but generally implies an increase of digestibility and/or protein content. However, for practical animal nutrition purposes, the goal should be well defined and could combine many factors, such as an increase in the intake of digestible nutrients by the animals. Other factors can be equally important and gains in one aspect are likely to cause a loss in other aspects. The nitrogen aspects of straw quality and their relation with digestible energy value of the straw are discussed by Walli *et al.* (1993) and toxicity by Deodhar and Gupta (1988). This paper will focus exclusively on the intake of digestible organic matter (DOMI), consisting of DMI, OMD and OM content of the fermented materials:

$$DOMI = OM * OMD * DMI \qquad (1)$$

A high DOMI requires one or more of the following factors:
- a high intake of fermented straw;
- reduced losses of organic matter;
- an increased OMD.

This means that maximization of DOMI can imply that a decrease of OMD or OM content is compensated by an increase in OMI.

Organic Matter Digestibility (OMD_t)

Not many *in vivo* digestibility values of fungal treated straws are available, hence the digestibility values used for our model have to be derived from *in vitro* values. The digestibility of straws in SSF change with time, expressed in our model as OMD_t. Generally at the beginning of the fermentation, the OMD of the substrate will decrease because the easily solubilized substances are used by the fungi. In the following stage, substrate polymers could be decomposed and sugars and other components of the substrate could be liberated. As a result the digestibility might

increase after an initial decrease (Zadrazil and Brunnert 1982; Badve *et al.*, 1987), though not necessarily returning to the same level.
The change in OMD depends on the fungal species, duration of fermentation period, temperature, water/air ratio and gas composition in the substrate, on the preparation, bulk density and the composition of the substrate.
In the calculations two situations have been considered: one in which the fungus will not decompose polymers, resulting in an ever decreasing OMD ("fast growing", e.g. *Coprinus* spp.), and one fungus which can decompose polymers, resulting in an increased OMD after an initial dip ("slow growing", e.g. *Pleurotus* spp.).

Organic matter content (OM_t)

Our model uses OM content in dry matter (OM_t) on the basis of literature data, by recalculating them from ash contents and DM losses (the DM loss can be supposed to consist entirely of OM loss). The OM_t is assumed to decrease linearly as the fermentation period progresses. OM decreases because the micro-organisms consume organic constituents for own metabolism. As a result of the OM loss, the ash content of fermented/spent rice straw can increase up to 30-33% or even further (Langar and Bakshi, 1986; Gupta *et al.*, 1988; Basuki and Wiriyasasmita, 1987). A general formula for organic matter content overtime is

$$OM_t = OM_o + bt \qquad (2)$$

Where:
OM = organic matter, kg/100 kg dry matter,
t = time after inoculation of fungus (days),
b = organic matter loss (% per day).

Two types of crop residues have been considered in the case study, i.e. a high and a low ash containing material (rice straw and sugarcane bagasse). The corresponding intial OM contents (OM_o) are 80% and 98% of rice straw and sugarcane bagasse respectively.
In our calculations of Tables 1 and 2, "t" ranges from 0 to 25 days ("fast growing") and 0 to 50 days ("slow growing) and b = 1.4 respectively 1 % for the "fast growing" and "slow growing" situation.

Dry Matter Intake

The total amount of DOM at time "t" is the product of OMD_t and OM_t:

$$DOM\% = OM\% * OMD\% \qquad (3)$$

This DOM may be used to estimate the economic value from the nutritive value by comparing with other feeds as done by Schiere *et al.* (1987). DOM is approximately the same as TDN, if the feeds

Table 1 Change over time in DOM and necessary change of DMI (to obtain at least an equal DOMI) of rice straw and bagasse as affected by fermentation by "fast growing" and "slow growing" fungi

Particulars	Fermentation periods				
"Rice straw-fast growing fungus"					
OM loss (%)	0	10	20	30	40
OM (%)	80	78.3	76.2	73.7	70.6
OMD (%)	50	47.0	44.5	42	40
DOM (%)	40	36.8	33.9	30.9	28.2
Δ DMI (%)	-	8.7	18	29.2	41.6
"Rice straw-slow growing fungus"					
OM loss (%)	0	10	20	30	40
OM (%)	80	78.3	76.2	73.7	70.6
OMD (%)	50	43	50	53	52
DOM (%)	40	33.7	38.1	39.1	36.7
Δ DMI (%)	-	18.8	5	2.49	
"Bagasse-slow growing fungus"					
OM loss (%)	0	10	20	30	40
OM (%)	98	97.8	97.5	97.2	96.7
OMD (%)	50	43	50	53	52
DOM (%)	49	42.1	48.8	51.5	50.3
Δ DMI (%)	-	16.5	0.5	-4.9	-2.6

Note: assumptions based on Rai et al. (1989) and Singh et al. (1989) for rice straw and on BIOCON (1988) for bagasse

Table 2 Animal performance on biologically treated straw.

Source	Animal species	Treatment	OM (%)	OMD (%)	DMI (g/d)	DOMI (g/d)
RICE STRAW						
Rai et al. (1987)	Goat	UTS[1]	76.6	65.6	551	281
		FTS[2]	67.5	55.9	750	282
Rai et al. (1989)	Goat	UTS[1]	77.4	64.5	652	320
		FTS[2]	70.2	66.2	1073	500[3]
Singh et al. (1990c)	Goat	Control	79.4	71.5	?	747
		FTS[2]	72.2	60.2	?	582
WHEAT STRAW						
Walli et al. (1987)	Goat	UTS[1]	85.0	48.4	445	183
		FTS[2]	80.0	46.3	550	204
Chaudhary et al. (1988)	Heifer	Control	82.6	53.5	4190	1860
		FTS (Spent)	78.2	49.5	4320	1700
		UTS[1]	87.6	61.6	4280	2300

[1] urea treated straw; [2] biologically treated straw after urea pre-treatment; [3] Interrelated with a higher intake of molasses of the FTS group

are of low fat content such as poor quality crop residues and fodder.

However if an increase in intake of digestible nutrients is the objective of the research, due attention should be given to the effect on DMI. In Table 1 the necessary increase in DMI is calculated to achieve at least a similar DOMI as with non-fermented crop residues (assuming a DMI of the original substrate of 6 kg). If higher increases in DMI can be achieved, this will result in a higher DOMI and, probably, a higher animal production. Actual DMI values are scarce but few are given in Table 2.

The calculations

The combined effect of changes in OM_t and OMD_t as affected by time (t) on DOM and necessary change in DMI is calculated for three situations (Table 1):
- a high ash substrate (rice straw) with a "fast growing fungus" (*Coprinus*),
- a high ash substrate (rice straw) with a "slow growing fungus" (*Pleurotus*),
- a low ash substrate (bagasse) with a "slow growing fungus" (*Pleurotus*).

The objective of these calculations is to prioritize further research on this subject by an assessment of:
- the impact of OM% of the original substrate,
- the relative importance OMD and DMI.

RESULTS AND DISCUSSION

In the case of "fast growing fungus" on rice straw, a decrease in OMD from 50 to 40%, combined with an OM loss of 40%, leads to a DOM decline from 40 to 28.2%. This decline is both an effect of the fermentation of the soluble parts and of the inability of fungi to break down the lignocellosic structure, resulting in both a lower OMD and a lower OM%. This means that the OM losses aggravates OMD losses. The OMD would have to increase from 50 to 56.7 to compensate the OM losses.
Also in the case of the "slow growing fungus" the DOM decreases from 40 to 39.1% after 30 days due to the OM losses, even though the OMD was assumed to increase from 50 to 53% after 30 days. This means that in high ash containing substrates like rice straw it is unlikely that DOM will be increased even if OMD is increased, due to the large impact of OM losses. Similar OMD and DOM patterns have also been shown by Schiere *et al.* (1987).
In low ash containing substrates like bagasse, the effect of OM losses on DOM is less severe. In the case of an increased OMD ("slow growing fungus"), the DOM increased from 49 to 51.5% after 30 days, even though the OM losses were assumed to be 30%.
The increased OMD is of importance because crop residues are a potential source of energy for ruminants. However the intake of energy (= DOMI)is not only dependent on OMD and OM but also on DMI. Calculating the necessary increase in DMI in order to have an equal DOMI as compared with the non-fermented substrate, it revealed that the DMI is to be increased by 41.5% in the case of "rice straw-fast growing fungus", while it might be decreased by 4.9% in the case of "bagasse-slow growing fungus".

This indicates that the scope in substrates like rice straw for fungi positively affecting the digestibility is limited due to the high effect of OM-losses on DOM, unlike substrates like bagasse where this effect is much smaller. It also indicates that the usefulness of biologically treated straw should not be evaluated on the basis of OM loss and digestibility alone, but that the DMI is an important parameter which should be taken into account also before drawing conclusions about the effectiveness of straw fermentation.

LIMITATIONS

Changes of DOMI over time are generally not studied through *in vivo* feeding trials, though the optimization of the process urgently requires such data. Some data of *in vivo* trials with straw are given in Table 2. These trials confirm that DOM is decreased due to OM-losses and decreased (or at best equal) OMD, while in some cases a higher DMI outweigh this lower DOM. Also little information is available on (a) potential (combination of) fungi that can effectively increase DOMI in non-sterile SSF, while toxicity due to contamination with other fungal strains warrants caution for the application under field conditions.

CONCLUSIONS

The focal point for evaluation of fermented straw should be the absolute DOMI rather than the OM losses or OMD alone, if increasing the intake of digestible nutrients is the aim of biological treatment. In that case fungal strains should be selected that increase DOMI, where a loss in digestibility can be compensated by an increase in DMI or *vice versa*. For optimization of the process (if at all possible) one has to know changes of DOMI components over time, which requires experiments at different treatment duration.

The results available in literature so far, mainly focussing on OMD and OM-losses, are not encouraging for the biological treatment from a ruminant nutrition point of view. However, little information on changes over time and DMI are reported. The results of the modeling, based on this limited information, suggest that the low ash containing roughages are better suited for fungal treatment than high ash containing material, while DMI appears to be of overriding importance.

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STUDIES ON *COPRINUS FIMETARIUS* INOCULATED STRAWS AND FUNGAL TOLERANCE TO AMMONIA

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SUMMARY

The Karnal Process uses Coprinus, *a fungus that grows in an alkaline medium at ammonia concentrations, that normally are considered to exert a fungicidal action. This paper discusses some of the information on the* Coprinus *tolerance to ammonia, the occurrance of microbial contaminants during the SSF and studies on the incorporation of ammonia or nitrogen compounds in the fungal mycelium. It is observed that the* Coprinus fimetarius *had NH_3 tolerance capacity up to 0.1% under liquid broth conditions. In fungal treated straw, as prepared with the Karnal Process, the percentage of contaminants like* Aspergillus, Mucor, Fusarium, Absidia *and* Penicillium *were as low as 30-35%. The protein content of* Coprinus fimetarius *inoculated rice and wheat straws through Karnal Process was 14.63% and 13.38% respectively. The amino-N content was higher (609.70 mg/100 g) in fungal treated straw than observed in untreated (331.29 mg/100 g) or urea treated straw (292.40 mg/100 g), i.e. higher than what could be expected on the basis of organic matter losses. The concentration of amino acids were also increased to 812.35 and 577.30 μ mol/g in fungal treated wheat and rice straw respectively.*

INTRODUCTION

The low nutritive value of straw is discussed elsewhere in this workshop (Singh and Oosting, 1993; Singh *et al.*, 1993). Attempts have been made throughout the world to upgrade straw into good quality animal feed by physical, chemical and biological means. The socalled two stage Karnal process was developed by Gupta and co-workers (Gupta, 1988) for biological treatment of cereal straws. In the first stage, the straw is treated with 4% urea and 40% moisture, and ensiled for 30 days, In the second stage, the *Coprinus fimetarius* fungus is inoculated on urea treated straws and incubated for 5-7 days at 37-40 °C (Kumar and Singh, 1990).

Coprinus fimetarius is an alkalophilic fungus which can grow at a high pH (up to 9) and a temperature of up to 42°C. Ammonia normally acts as an aerobic deterioration inhibitor (Bothast *et al.*, 1973; McDonald, 1981; Goddard, 1990) but *Coprinus fimetarius* appears to have the ability to grow in presence of ammonia. The NH_3 tolerance and the capability to incorporate ammonia related compounds into *Coprinus fimetarius* mycelium were studied in detail and results are presented here.

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MATERIALS AND METHODS

A liquid broth was prepared to test the tolerance of Coprinus to increasing NH_3 concentration. The ammonia concentration in glucose broth (glucose 40 g, yeast extract 1 g, peptone 1 g, water 1000 ml, streptomycin 30 μg/ml broth) was kept at different levels and the millet based inoculum of *Coprinus fimetarius* (Singh *et al.*, 1989) was inoculated at the rate of four seeds per 50 ml broth. The flasks were incubated at 37°C for one week. Mycelium of the fungus was then harvested and washed twice with distilled water, centrifuged, freeze dried and weighed. Total N of the samples was determined by Kjeldahl method (AOAC, 1980). The amino acid composition was determined using the Beckman automatic amino acid analyser (Gupta *et al.*, 1993) and the amino-N was also estimated (Gupta, 1988)

The solid substrate fermentation (SSF) products of wheat and rice straws were prepared as per the Karnal Process (Gupta, 1988). The fungal cultures from the SSF-stack were isolated during the fermentation of straws and identified at the Mycology Department, IARI, New Delhi.

RESULTS AND DISCUSSION

Ammonia-capture capability

An increase of CP content of wheat and rice straws by *Coprinus fimetarius* treatment through the Karnal Process is clear from Table 1. Within 5 days after inoculation profuse growth of the fungus was observed and the CP content of fungal treated wheat straw increased from 3.51% (in untreated straw) to 13.38% in treated straw. The experiments with rice straw gave similar results as for wheat straw and the CP in fungal treated rice straw increased to 14.63%. A similar trend was observed in several previous experiments, and as such as the concepts of NH_3 compound "trapping" or incorporation by the fungus was put forward (Gupta, 1988). The amino-N content in the treated straw was also determined and found to increase more than two times after fungal treatment of rice straw (Table 2). The amino acid analysis of the untreated, urea treated and *Coprinus fimetarius* treated wheat and rice straws showed that while there was a substantial increase in the total amino acids on fungal treatment of both straws on urea treatment alone was comparatively small (Figure 1). This indicated that during simple urea treatment, the ureolytic and other micro-organisms contributed to minor increase in the amino acid content. The substantial increase in the amino acid content on the fungal treatment indicated that the NH_3 compounds "trapped" by *Coprinus fimetarius* was mainly utilised for amino acid synthesis for the formation of fungal proteins during mycelial growth. Others also report that protein content of straw can be increased after its inocculation with different organisms along with addition of an inorganic form of nitrogen (Han and Anderson, 1975; Han, 1978; Moo-Young *et al.*, 1981;

Zadrazil, 1984; Walli *et al.*, 1993).

Table 1 Increase in CP value of straws by *C. fimetarius* treatment through the 'Karnal Process'.

Particulars	% DM basis			
	Wheat straw		Rice straw	
	N	CP	N	CP
Untreated	0.56	3.51	0.79	4.92
4% urea treated	1.42	8.87	1.35	8.45
C. fimetarius treated	2.14	13.38	2.34	14.63

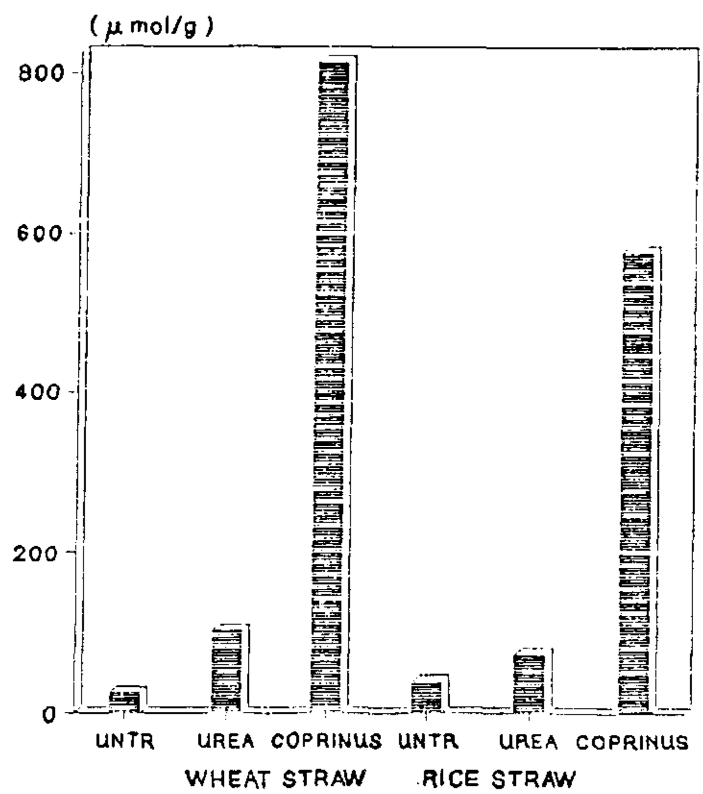
Source: Gupta (1988)

Table 2 Amino-N concentration in *C. fimetarius* treated rice straw

Particulars	NH_3-N content (mg/100 g wet substrate)
Untreated	331.29
Urea treated	292.40
Fungal treated	609.70

Source: Gupta and Singh (1991).

Figure 1 Total amino acid content of untreated urea and *C. fimetarius* treated straws (Source: Kishan Singh *et al.*, 1992).



Microbial contaminants

The microbial mass in the inoculated and fermented material comprised 65% fungal isolates from Coprinus and the other 35% consisted of Mucor, Aspergillus, Absidia, yeast and Penicillium (Table 3). *Aspergillus flavus* is known to produce toxins at 25°C in pure culture medium (Diener and Davis, 1966). However, while the *Aspergillus* sp. formed only 7.5% of the total fungus in the fermented straw, the amount of *Aspergillus flavus* was insignificant. Therefore, the chances of toxin production in the SSF at high temperature using *Coprinus fimetarius* are low, though not nil. It is interesting to know in this respect that ammonia is commonly used to de-activate mycotoxins (Deodhar and Gupta, 1988). The method of the SSF must be relatively rapid and reliably reproducible to reduce the occurrance of microbial contamination during the fermentation of crop-residues (Flegel, 1988b).

Table 3 Percent contamination of isolates from urea treated wheat straw inoculated with *C. fimetarius*.

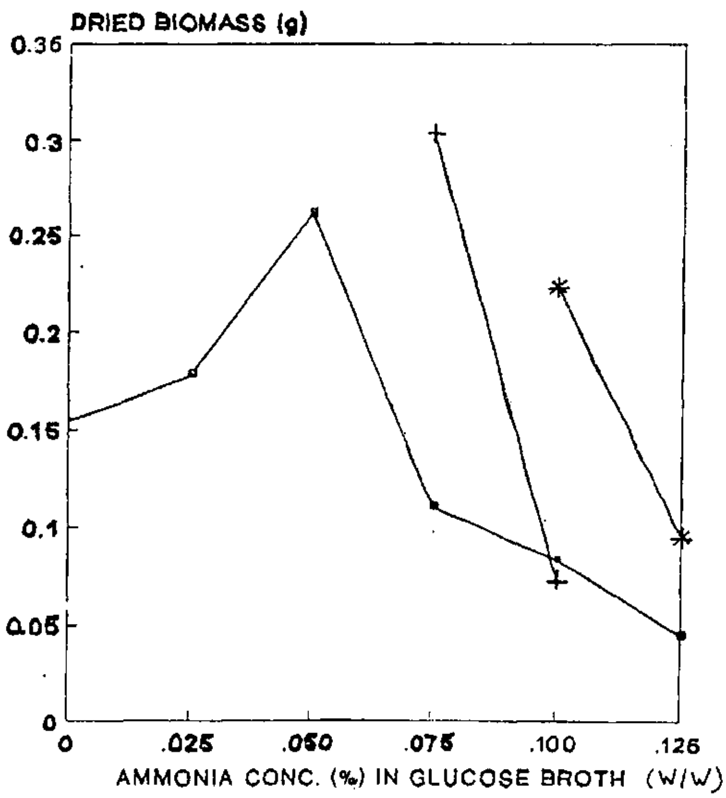
Isolates	Contamination (percent of total organisms)
Mucor sp.: M. indicus, M. reacemosus, M. variosporus, M. circinelloides, M. bainieri, M. Hiernalus	15.0
Aspergillus sp.: A. flavus, A. fumigatus, A. terreus	7.5
Absidia sp	5.0
Penicillium sp.	2.5
Yeast spp.	2.5
Coprinus fimetarius	65.0
Unidentifiable	2.5

Source: Kumar and Singh (1990)

Ammonia tolerance

The results of ammonia tolerance trials of *Coprinus fimetarius* (Figure 2) showed that the fungal biomass production was highest (0.2610 g) at 0.05 (% V/V) concentration of ammonia. The biomass production of *Coprinus fimetarius* decreased as the ammonia concentrations increased beyond 0.05%. In another experiment therefore, mycelium that originated from 0.05 (% V/V) ammonia tolerance was tested further at 0.075% NH_3 concentrations. The fungal biomass produced at that level was 0.3043 g, indicating a possibility to increase NH_3 tolerance of *Coprinus fimetarius* beyond 0.05%. In view of this, mycelium of 0.05 and 0.075% NH_3 tolerance were prepared and tested for biomass production at different NH_3 concentrations in liquid medium and the results are presented in Figure 2, showing that a fungal biomass production of 0.2232 g was possible even at the concentration of 0.10% NH_3 in broth when the ammonia tolerance of *Coprinus fimetarius* mycelium was increased step by step from 0.05 to 0.075% and again from 0.075 to 0.10%. This is still much lower than NH_3 related compound concentrations in treated straw, but the same growth was observed even at higher concentration of NH_3 related compunds (0.35 to 0.54%) during the SSF of straws. Apparently, therefore, the NH_3 related compounds when on high concentration gets adsorbed on the straw which in turn enables the *Coprinus fimetarius* to grow on straw unlike the conditions in the broth (Flegel, 1988).

Figure 2 Ammonia tolerance of *Coprinus fimetarius* in glucose broth (Source: Kishan Singh *et al.*, 1992).



CONCLUSIONS

The protein content of *Coprinus fimetarius* inoculated wheat and rice straws through the Karnal Process increased as it incorporated NH_3 compounds which are generated from urea in the first stage of the SSF process, converting them into biological protein as also illustrated by the increase in amino-N and amino acids in fungal treated straws. Which ammonia compounds are exactly incorporated still deserves further study.
The percentage of contaminants were 30-35%, and methods should be developed to reduce these contaminants as they increase the chances for mycotoxin formation.
Coprinus fimetarius tolerates an NH_3 concentration of up to 0.1% under liquid broth conditions, which are much lower than the levels that are likely to occur in the SSF which originates from ammonia treated straw such as in the first stage of the Karnal Process. The explanation for the growth of fungus must be sought in differences between liquid broth and SSF, where in the latter

not all ammonia may be available in free form, or where it may occur in chemical forms that do not depress fungal growth. Further work on these issues is warranted to better understand and manipulate the processes.

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NITROGEN STATUS OF BIOLOGICALLY TREATED STRAW AND ITS N-UTILIZATION BY ANIMALS

T.K. Walli[1], S.N. Rai[1], G.P. Singh[1] and B.N. Gupta[1]

SUMMARY

Most of the biological treatments of straws by lignocellulolytic fungi which aim to improve the nutritive value (i.e. mostly to increase OMD) are associated with organic matter (OM) losses during fermentation. The two stage 'Karnal Process' aims however to improve the N-status of the urea treated straw (UTS) by using Coprinus fimetarius, *which converts N-compounds into fungal N, with a minimum loss of OM. In a series of trials the period of fermentation was reduced to 5-6 days and the OM loss to only 7-8%. The fungal biomass production during fermentation was calculated from the chitin content of the fungal treated straw (8.54%), whereas the chitin content of the pure fungal mycelium was 11.7%. During fungal growth, the soluble N and NH_3-N (as % of total N) decreased from 68.18 and 48% on day zero to 26.78 and 3.96% on day 7 respectively, while the insoluble N other than ADIN increased from 19.96% on day zero to 50.24% on day 7. The incorporation of N compounds in fungal N during fermentation was confirmed by an amino acid N concentration that showed a two fold increase over that of UTS. Most of the amino acids concentrations in the fungal treated straw (FTS) increased, especially arginine, serine, glutamine, glycine, aspartic acid and threonine. The increase of CP value in FTS can be attributed to OM loss and to the capture of N-compounds by the fungus, leading to an N/DOM ratio that was wider in FTS than in UTS. Goat feeding trials showed higher N-retention for the FTS fed groups than for UTS groups. With cross-bred calves, the N balances were similar, although the calves on FTS received 30% less groundnut cake than the ones given UTS. The trial with rabbits did not show any significant difference in N intake or N excretion after feeding UTS or FTS. Thus, the* Coprinus *treated straw by "Karnal Process" appears to enhance the N status of the straw over urea treated straw, but needs supplementation with energy to make it a good ration for ruminants, though the desired production level will determine the suitability of the feed. The N-retentions did not tally well with liveweight gains.*

INTRODUCTION

In most of the studies on biological treatment to improve the nutritional quality of straw as an animal feed, the emphasis has been on maximum lignolytic activity of the fungus at minimum OM-loss and maximum increase of OMD (Han and Anderson, 1975; Kirk *et al.*, 1976; Zadrazil, 1977; Chahal and Moo-Young, 1981; Agosin *et al.*, 1985; Flegel and Meevootisom, 1986). It is commonly assumed that the effect of (biological) treatments of straw can

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be evaluated on the basis of DOM recovery, modification or loss of lignin, availability of residual cellulose and hemicellulose and the palatability and safety of the final fermented product as animal feed. Rai *et al.* (1993) and Schiere *et al.* (1987) argue that it is in fact the final digestible organic matter intake (DOMI) that counts and that a reduction of one factor (OMI, OMD or OM%) can be compensated for by an increase in another. Attempts to increase DOMI have however not been very successful to date as discussed elsewhere in these proceedings. This paper discusses aspects of nitrogen metabolism that normally receive little attention.

The treatment by fungi takes place in two phases. In the initial phase, the fungus colonizes the substrate using the early available carbohydrate and nitrogen sources to synthesize a lignolytic enzyme system. In the second phase, the lignin is degraded (Zadrazil, 1977; Fenn and Kirk, 1981). Secondary metabolic activities appear on termination of growth on a medium containing sufficient and balanced nutrients, and the primary growth phase starts when hydrolytic cellulase activity can be induced. Such primary growth ceases when the organism exhausts available carbon, nitrogen and sulphur and the secondary metabolic activities are initiated. These include induction of ammonia permease activity (Keyser *et al.*, 1978), changes in the balance of enzyme involved in glutamate metabolism, a key intermediate in N metabolism, (Buswell *et al.*, 1982), an enhancement in adenyl cyclase activity, resulting in an increase in intracellular cyclic AMP (McDonald *et al.*, 1985), followed by the production of lignin peroxidase and the secretion of the secondary metabolite veratryl alcohol, the presence of which enhances the lignin biodegradation process.

Nitrogen metabolism in the first phase plays an important role in regulating the initiation or suppression of the secondary metabolism, the lignolytic activity being one such secondary process (Fenn and Kirk, 1981). In a N-rich medium, a suppression in lignin degradation has been observed (Kirk *et al.*, 1976, 1978; Zadrazil and Brunnert, 1980, 1982), possibly because high nitrogen levels promote rapid depletion of energy sources (Kirk *et al.*, 1976) and the increased formation of fungal biomass, which in turn speeds up the rate of respiration (Reid, 1979). There seems to be some requirement for essential growth factors which are common to both N metabolism and lignin degradation pathways.

In the two stage "Karnal Process" the situation is somewhat different (Gupta *et al.*, 1988a; Rai *et al.*, 1988a). The urea treatment of the first stage helps to loosen the lignocellulosic bonds (Chesson, 1981) and in the second stage i.e. the fermentation of urea treated straw by *Coprinus fimetarius*, the excess ammonia-compounds are captured by fungus for conversion into a more stable form of N. This paper discusses aspects of N metabolism associated with the treatment of straw by *Coprinus fimetarius*.

Crude protein content

Wheat and paddy straw fermented by *Coprinus fimetarius* under non-sterile conditions at Karnal (Gupta *et al.*, 1988a, b; Rai *et al.*, 1989) showed an increase in CP content (Table 1) over urea treated straw, containing part of its N in volatile form, some of which is likely to be lost before feeding by evaporation. Zadrazil (1977) used steam treated straw inoculated with *Pleurotus* sp. without any additional N source. He reported an increased in N content of straw, attributed to CO_2 losses during fermentation. Bakshi *et al.* (1985) also reported an increase in the CP content of spent wheat straw from 2.49% in untreated straw to 4.70% after harvesting of mushrooms using *Pleurotus* sp. In spent rice straw, Langar and Bakshi (1986) found CP values of 4.32 to 8.31% for untreated and urea treated straw respectively, while using *Volvariella sp*. Lauketics *et al.* (1984) and Badve *et al.* (1987) also reported an increase in the CP content of urea treated straw and bagasse after fermentation with *Coprinus 386* culture.

It is unlikely that the increase in N content during fermentation is due to direct fixation of any atmospheric N by fungi (Rajarathnam and Zakia Bano, 1989) though fungi can possibly incorparate N-compounds that are first fixed by other microorganisms (King *et al.*, 1980). Relative CP increases are probably due mainly to loss of OM as CO_2 during the fermentation. In the urea treated straw (UTS) a substantial proportion of the N is present as free NH_3, much of which escapes before the straw is consumed by the animals. In the biological treatment involving fermentation of urea treated straw by *Coprinus* sp.; the fungus is likely to capture these volatile N-compounds as fungal N.

Nitrogen transactions during the fermentation

Measurement of different N fractions in straw during the second phase of the Karnal process expressed as per cent of total N (Figure 1) indicated a decrease in soluble N and NH_3-N, a slight increase in ADIN and a larger increase in non-ADIN insoluble N, the fraction which is most likely to be fungal N. After correcting for DM-loss, these changes expressed revealed a similar trend (Table 2), although the total N in straw decreased as the fermentation proceeded, which could be attributed to evaporation of N-compounds such as NH_3. The reduction in NH_3-N content, combined with the substantial increase in insoluble N (non- ADIN) content could have occurred by incorporation of N-compounds into fungal N. The extent of N-compound incorporation (trapping) by Coprinus fungus has been shown to be 77.6 and 77.9 per cent in the urea treated wheat and paddy straw respectively, the rest being evaporative losses (Gupta, 1988a, b). Following semi-solid fermentation of ammoniated rye grass by cellulomonas sp. an increase in organic N has been observed (Han *et al.*,

Table 1 CP content of straw before and after the fungal (*Coprinus*) treatment.

Type of straw	% of urea for urea treatment	Moisture (%)	Period of fermentation (days)	CP content			References
				Untreated straw	Urea treated straw	Fungal treated straw	
Wheat	3	70	30	2.85	7.12	10.12	Walli et al., 1987
	3	65	14	2.65	5.52	7.75	Walli et al.
Paddy	4	65	30	4.31	12.58	14.13	Rai et al., 1989
	4	65	14	-	11.21	12.70	Rai et al., 1989
	4	65	7	3.40	8.14	13.76	Gupta, 1988a
	4	65	7	4.80	7.87	11.78	Gupta, 1988a

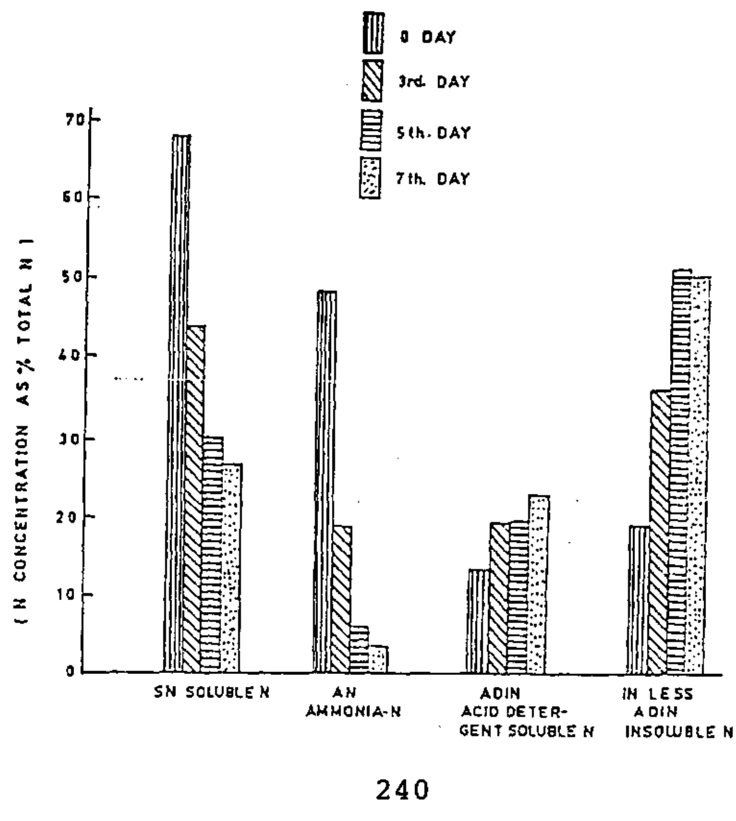
Note: The lower values of CP in the urea treated straw can partly be caused by evaporation on NH_3 compounds.

Table 2 Changes in N fractions (% of DM) of wheat straw during different periods of fermentation after correcting for DM loss.

Day of	Total-N	Soluble-N	Ammonia-N insoluble N	Insoluble-N	ADIN	NON-ADIN
Zero hour	1.72	1.17	0.83	0.55	0.23	0.33
3rd day	1.70	0.74	0.32	0.96	0.33	0.61
5th day	1.69	0.51	0.10	1.18	0.33	0.86
7th day	1.57	0.42	0.06	1.15	0.36	0.79

Source: Walli et al. (1988).

Figure 1 Changes in N fractions of fungal treated wheat straw at different days of fermentation.



1978). Langar and Bakshi (1987) showed that the stacking of urea straw mixture at 70 percent moisture for 9 days favoured microbial protein synthesis by the predominant thermotolerant and thermophilic micro-organisms. Thus, in the two stage Karnal process, the CP content is higher than in urea treated straw, which is due to N capturing. However, after correcting for DM loss, there is a slight decrease in the N content in FTS during fermentation as evaporative N loss, though quite lower than compared to the evaporative N loss in urea treated straw (Table 2).

Chitin and biomass production

The N-compounds incorporated by the fungus are supposedly distributed among the three components of the fungal biomass, i.e. true protein, chitin and nucleic acids (Flegel and Meevootisom, 1986). Methods to assess the fungal growth and biomass production during solid state fermentation, include use of markers such as chitin, nucleic acids, ATP, ergosterol estimations, or ELISA and RIA techniques for certain enzymes related to growth, N^{15} incorporation, O_2 consumption and CO_2 evolution from colonized substrate, substrate consumption or hyphal length measurements (Matcham *et al.*, 1984).

Chitin is an insoluble linear polymer of N acetyl glucosamine units and an integral part of the hyphal wall of most fungi. Chitin is totally absent in plants, most animals and other microorganisms (Rosenberger, 1976). Its use as a marker to estimate the fungal biomass has been the subject of critical appraisal (Whipps and Lewis, 1980). Chitin content of Coprinus mycelium estimated by the Chen and Johnson (1983) method, was 11.70% of the dry mycelial weight, from which a factor of 8.54 was derived (Table 3) to calculate biomass production in straw during fungal growth (Table 4). Agosin *et al.* (1985) found a chitin content ranging from 3.4 to 6.7 per cent of the dry mycelial weight. During the Karnal process a good mycelial growth can be obtained within just 5 days, provided the proper conditions like moisture, aeration, humidity and temperature are maintained during fermentation (Gupta, 1988b). The DM loss was 7.56% at day 5, increasing to 23.35% by day 7, suggesting use of cellulose and hemicellulose by the fungus.

Estimations of N transactions suggest that the soluble N-compounds (probably NH_3) were trapped by the fungus and incorporated in its biomass as fungal N. Subsequent measurements of the amino N and amino acid composition (Table 5) confirmed that the fungus is able to synthesise amino acid and proteins from the excess N-compounds available from UTS during the fermentation process (Gupta, 1988b). Some of the amino acids recorded a large increase like arginine, serine, glutamic acid, glycine aspartic acid and threonine. An increase in cystine was hardly detected.

Table 3 Cell wall and chitin content of *Coprinus fimetarius*.

Fungal cell wall (% of total mycelium)	58.83
Chitin content	
% of fungal cell wall	19.88
% of total mycelium	11.70
Ratio of mycelial biomass chitin	8.54

Source: Walli *et al.* (1988).

Table 4 DM loss, chitin and biomass content and DM loss during fermentation of wheat straw by *Coprinus fimetarius*.

Period of fermentation (days)	Chitin (%)	Fungal Biomass (%)	DM loss (%)
3	2.93	25.02	6.60
5	3.37	28.78	7.50
7	4.27	36.46	23.35

Source: Walli *et al.* (1988).

Table 5 Amino acid-N and concentration of some of the amino acids in untreated and treated wheat straw (μmol/g).

	Type of wheat straw		
	Untreated	4% urea treated	Coprinus treated
Amino N (mg/100g)	331.3	292.4	609
Amino Acid content (μmol/g)			
Amino-Acids with large increase recorded			
Arginine	0.34	1.26	103.57
Serine	1.75	9.98	128.95
Glutamic Acid	5.99	24.65	171.98
Glycine	3.41	14.88	113.71
Aspartic acid	3.78	21.98	89.59
Threonine	1.51	5.98	57.42
Amino-Acids with medium increase recorded			
Methionine	0.24	2.25	20.60
Isoleucine	0.84	5.04	30.30
Proline	0.64	4.06	22.17
Leucine	0.47	2.07	17.11
Valine	0.48	2.16	14.13
Lysine	0.56	2.17	9.73
Total Amino acids	24.71	102.80	812.35

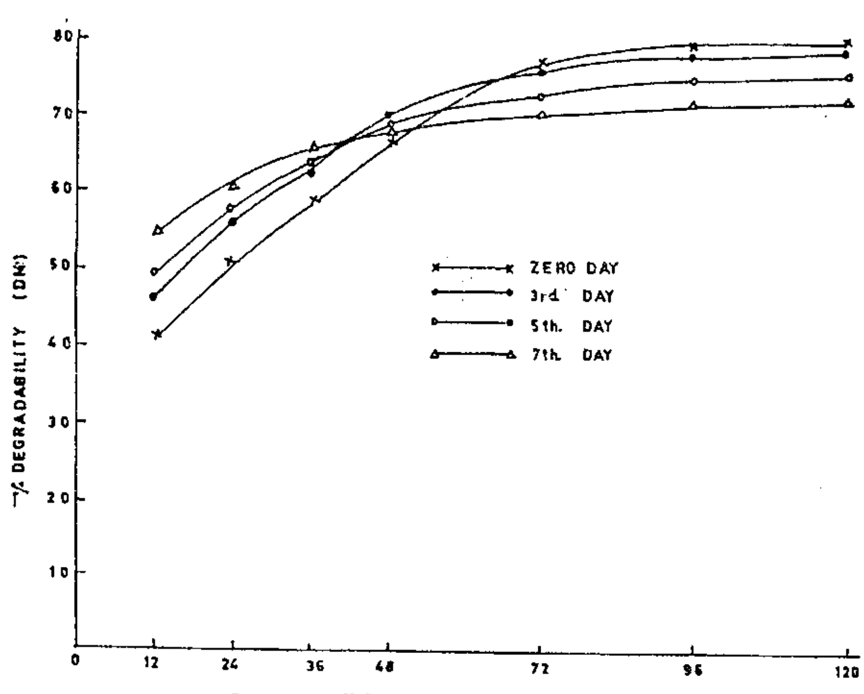
Source: Gupta (1988a, b).

Dry Matter Digestibility

Zadrazil (1985) tested around 200 white rot fungal cultures on wheat straw and found an increase in *in vitro* digestibility from 15-32 units in most of the cases, depending upon temperature and period of fermentation. Zadrazil (1984) also reported decreased digestibility in some cases after fungal treatment and a larger review of these and other responses is given by Basuki and Wiryasasmita (1987). Kamra and Zadrazil (1987) suggested that the *in vitro* digestibility of lignocellulosic substrates is one of the most important criteria for the selection of fungal cultures, but if OM loss and OMI are not taken into account, the results of *in vitro* digestibility alone could be misleading (Schiere *et al.*, 1987; Rai *et al.*, 1993).

After the effect of NH_3 on the lignocellulose complex in straws during the urea treatment, there is less likelyhood of further lignolytic activity during the second stage i.e. during the fermentation by Coprinus fungus. Kirk *et al.* (1976) and Zadrazil and Brunnert (1980; 1982) even observed that the lignolytic activity is suppressed in N-rich mediums. The potential degradability of FTS by nylon bag technique shows a constant reduction as the fermentation proceeds from zero to 7 days (Figure 2). However, the initial decrease in *in vitro* digestibility tends to be compensated with an increase when samples are subjected to a longer period of solid state fermentation (Zadrazil and Brunnert, 1982; Badve *et al.*, 1987). This could be attributed to an initial consumption of soluble carbohydrates by the fungus, and a subsequent solubilization and the subsequent change in the texture of straw, being more brittle than urea treated straw.

Figure 2 Degradability of fungal treated wheat straw.



Nitrogen utilization by animals

Feeding trials with goats on urea treated (UTS) and fungal treated paddy straw (FTS) showed a significantly higher ($P < 0.01$) N intake on FTS than on UTS, due to both a higher DM intake or a higher N content in FTS, i.e. 0.95 + 0.13 and 1.63 + 0.21 g/kg $W^{0.75}$. N retention was also significantly higher on FTS(0.66 ± 0.08) than on UTS,(0.35 ± 0.03 g/kg $W^{0.75}$) (Walli *et al.*, 1988). The average values for N retention (as % of ingested N) was also higher on FTS than on UTS, however, the difference was not significant. The average CP content was higher for FTS (12.5%) than for UTS (9.3%) and the ratio of (N/DOM) was higher for FTS (5.16) than for UTS (3.34) suggesting that the energy value in relation to N is lower in FTS (Walli *et al.*, 1993).

In a feeding trial with calves, the N-balance was observed to be similar on FTS and UTS (Table 6) although the calves on FTS group received significantly lower ($P < 0.01$) amount of groundnut cake supplement, i.e. 30% less than that on UTS group to make the diets isonitrogenous. The results suggest that the quality of protein synthesised by the fungus during fermentation of straw through Karnal process was good enough to match GN cake protein. A feeding trial on pure albino-Haffkins strain rabbits (Table 7) to compare untreated, urea treated and fungal treated straw showed non-significant differences between the different treatments with regard to N intake, N excretions through dung and urine and the N balance as g/d and as % of N digested, although the values were slightly higher for N intake, excretion through dung and N balance for fungal treated straw. For DMI by rabbits, the average values were 37.96, 42.60 and 44.62 g/d for untreated, urea treated and fungal treated group, respectively (Gupta, 1988a).

Table 6 N-intake and N balance data on cross-bred calves fed urea treated or fungal treated wheat straw and supplemented with groundnut cake.

	Urea treated straw	Fungal treated straw
N Intake		
Total g/d	65.04 ± 3.70	64.00 ± 2.46
Total g/kg $W^{0.75}$	1.69 ± 0.19	1.68 ± 0.14
Intake from cake (% of total N)	59.32 ± 0.45	41.03 ± 2.02
N Retention		
g/d	12.86 ± 3.43	13.35 ± 1.94
g/kg $W^{0.75}$	0.34 ± 0.05	0.35 ± 0.02
% N intake	19.75 ± 4.90	20.85 ± 3.39
% N digested	34.60 ± 7.32	36.99 ± 3.39

Source: Walli et al. (1988)

Table 7 Intake, digestibilities and balances of N in rabbits fed diets containing untreated, urea treated or fungal treated paddy straw.

	Untreated straw group	Urea treated straw group	Fungal treated straw group
CP content (%)			
Straw	4.83	7.83	11.78
Straw + basal control diet	14.42	14.75	15.61
N intake (g/d)	0.872 ± 0.01	1.005 ± 0.02	1.110 ± 0.03
CP intake (g/d)	5.47 ± 0.07	6.28 ± 0.15	6.96 ± 0.54
CP digestibility (%)	84.30 ± 1.36	79.86 ± 2.32	73.67 ± 1.45
N Excretion (g/d)			
Through dung	0.137 ± 0.01	0.202 ± 0.02	0.224 ± 0.04
Through urine	0.145 ± 0.02	0.165 ± 0.02	0.133 ± 0.01
N Retention			
As g/d	0.558 ± 0.02	0.638 ± 0.04	0.681 ± 0.07
As % of N digested	80.06 ± 3.02	79.29 ± 2.41	88.69 ± 1.23

Source: Gupta (1988a).

The N-retention here appears to be high and cannot be explained. The trial was conducted for one month. Initially the animals took time to adjust to new feed, picked up the intake slowly and by the time the metabolic trial was conducted the animal on UTS consumed more straw. Initially the animal lost some weight (in the first week) then maintained and towards the end there was a nominal gain of 2.0 and 1.8 kg during the final 2 week period for UTS and FTS, respectively.

CONCLUSIONS

Coprinus treatment in the two stage Karnal process improved the N-status of animals on UTS and straw consumption also increased. Initially animals lost some weight (in the first week) then maintained and towards the end there was a nominal gain of 2.0 kg on urea treated straw, and 1.8 kg during the final 2 week period for UTS and FTS respectively. Fungus traps the volatile NH_3 compounds and incorporate it as organic-N, in the form of chitin-N, nucleic-N and amino acid-N. Thus, the volatile N, much of which would have been lost otherwise through evaporation, can not only be trapped by fungus, but part of it which is converted to amino acid-N, can provide the pre-formed amino acids needed by some species of rumen micro-organisms for their proliferation. However, it is likely that the energy could be the limiting component in such treated straw.

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BIOTECHNOLOGICAL APPROACHES OF STRAW UTILIZATION BY MICROBIAL SYSTEMS FOR FEED AND INDUSTRIAL PURPOSES

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SUMMARY

Development of the technology of lignocellulose utilization by white rot fungi and actinomycetes has improved the understanding of enzyme systems in the degradation of cellulose, hemicelluloses and lignin. While regulatory steps in the enzymatic holocellulose degradation are known, neither the cleavage of ligno(hemi)cellulosic bonds, nor the process of ligninolysis, are clearly delineated. The search continues to a) achieve genetic improvement of required microorganisms, and b) to optimize solid state and submerged fermentation systems for the utilization of lignocelluloses for animal feed, mushrooms and single cell protein. This paper discusses the biological treatment of lignocellulosic substrates with cellulase deficient mutants in the biopulping, biobleaching and bioconversion of lignocellulosis into useful industrial chemicals such as ethanol. The results obtained so far show the need for further studies on genetic improvement of specific microbial strains, control of fermentation as well as understanding of the fundamental enzymic systems, before field application is possible.

INTRODUCTION

The potential of lignoholocellulosics, hereafter called lignocellulosic agricultural waste for use as feed, food or chemicals for industrial application has received considerable attention in recent decades (Hartley and Shama, 1987; Zadrazil and Reiniger, 1988). In this context, the use of microbes to upgrade plant wastes depends largely on:

- the identification of a single or a combination of suitable micro-organisms,
- the genetic improvement of microbial strains for lignocellulosic degradation (Raeder et *al.*, 1987; Haemmerli et *al.*, 1988),
- the optimization of solid state fermentation (SSF) or submerged fermentative conversion (Reid, 1989).

This paper discusses the biochemical background of lignocellulosic breakdown and various industrial uses for these materials.

LIGNOCELLULOSE, ENZYMES AND MICRO-ORGANISMS

Lignocellulose consists of three major components: cellulose, hemicellulose and lignin (Sundstol and Owen, 1984). Cellulose is

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a chemically and structurally simple cellulose polymer of glucose, but not easily hydrolysed by microbial enzyme systems (Beguin *et al.*, 1988). Hemicelluloses are chemically and structurally more complex than cellulose since hemicelluloses are heteropolymers composed of hexoses, pentoses, minor sugars and uronic acids. Their enzymatic hydrolysis requires several hydrolytic enzymes, known as hemicellulases. These enzymes are distinguished on the basis of site of their action and in combination liberate constituent sugars.

Lignin is the most complex and least characterised constituent in the lignocellulose complex. Essentially, lignin is a three dimensional phenyl propane polymer with each monomer held together by ether or C-C bonds. Lignin degradation is an oxidative process and accordingly involves several oxidative enzymes particularly lignin peroxidases (ligninases), and other hydrolytic enzymes (Neelakantan, 1987; Haemmerli *et al.*, 1988; Neelakantan and Sondhi, 1988).

WAYS TO IMPROVE EFFICIENCY OF LIGNOLYTIC PROCESSES

Fungal species possess varying ability to degrade components of the lignocellulose complex. However, in contrast to other wood decomposing fungi, white rot fungi degrade all three major components viz. cellulose, hemicellulose and lignin (Zadrazil, 1984). The enzyme mechanisms for cellulose, hemicellulose and lignin degradation have been elucidated in numerous studies conducted on white rot fungi, especially *Phanerochaete chrysosporium*, *Sporotrichum pulverulentum*, *Trichoderma viride*, *T. reesei*, etc. (Broda *et al.*, 1989). The biodegradation of lignin and lignocellulose by white rot fungi and actinomycetes is studied by Kirk and Farrell (1987), and McCarthy (1987).

One of the problems with biological delignification is that the fungi require a cosubstrate to support the lignin metabolism. The relationship between lignolytic and cellulolytic activity should be balanced so as to ensure that lignin is degraded but without the cellulose being totally utilised as carbon and energy source. This problem can be solved to adopt either white-rot fungi which preferentially attack lignin, or to develop cellulase restricted or deficient (Cel^-) strains. The conditions of treatment should be optimized so that the degradation of lignin is favoured, whereas cellulose or hemicellulose degradation is supressed.

Genetic improvements of lignocellulolytic micro-organisms

Fungi are ideal tools for genetic analysis and the study of fungi, such as *Neurospora crassa*, *Coprinus* spp., *Polyporus* and *Phanerochaete chrysosporium* has contributed much to an understanding of genetic systems. The production of basidiospores allowed the adoption of classical genetical basidiomycete crosses which made way for the development of cellulase restricted strains utilizing xylan and with high lignin degrading capacity. The xylan breakdown was also desirable for several reasons, including that xylan is closely associated with the lignin and that the monomer xylose is a readily metabolisable sugar energy for lignin degradation.

The production of cel^- mutants with the desired characters involved selection, mutation and intercrossing of homokaryotic strains. In *P. chrysosporium*, it is possible to analyse the different components of the overall hydrolytic system and their relationship and techniques have been developed for its molecular genetics. Besides, the recent efforts on the efficient ligninolytic actinomycetes have shown higher lignin degradability because it has features that are novel and of biotechnological potential (Broda *et al.*, 1989).

P. chrysosporium has served as an excellent model system. It degrades a wide range of lignocellulosic substrates and a substantial body of biochemical and molecular genetic knowledge exists for it. Heterologous probing using genes from *P. chrysosporium* and *T. reesei* will allow the rapid development of molecular genetics for such organisms. *P. chrysosporium* ME446 strain possesses a unifactorial homogenic incompatibility system governing heterokaryon formation (Thompson and Broda, 1987). A very wide range of responses was observed when monospore cultures (derived from single basidiospores) were paired on agar plates, which included mutual antagonism, and compatibility resulting in secondary mycelium formation and a number of different types of behaviour between the two extremes. Studies on DNA reveal that the cell derived from dikaryotic mycelium is heterokaryotic with nuclei of two different genotypes. *P. chrysosporium* has a unifactorial homogenic incompatibility system facilitating the interpretation of previous genetical studies of this organism (Alic *et al.*, 1987) and provides a basis for the rational design of future experiments concerned with obtaining and manipulating mutants with altered ligninolytic and/or cellulolytic activities. The production of enzymes (e.g. lignin peroxidase) either by *P. chrysosporium* itself or by the cloned alternative hosts, such as yeast or *Trichoderma* producing exceptionally large amounts of extracellular cellulases has been achieved (Broda *et al.*, 1989). In the case of cel^- mutants of *P. chrysosporium*, residual sugars and/or hemicelluloses are utilized by the organisms for the production of H_2O_2.

The application of recombinant-DNA technology to cellulases produced by fungi and construction of new cellulolytic organisms have been reported (Knowles *et al.*, 1987). Besides, the use of genetic crosses for strain improvement in white rot fungi for lignocellulose utilization has been achieved (Raeder *et al.*, 1987). There is considerable potential for the application of genetic engineering techniques to these lignocellulolytic fungi, including the use of protoplasts and DNA transformation methods. These approaches, combined with strain selection methods, may provide improved strains which will allow noval biotechnologies to be introduced and further improve the economic viability of existing ones such as industrial potential in biopulping, bioconversion of feed, treating wastes and converting byproduct lignins to useful chemicals (Buswell and Odier, 1987; Haemmerli *et al.*, 1988).

DIFFERENT USES

Conversion into animal feed

Fibrous crop residues have very low feed value for ruminants because of their low usable energy and protein content. Poor digestibility is attributed to the close association of (hemi)cellulose with lignin and can be improved by chemical, physical or biological treatments. White rot fungal species with high ligninolytic activity include *Phanerochaete chrysosporium*, *Dichomitus squalens*, *Pleurotus* sp, *Lentinus edodes*, *Polyporus adustus*, *Cyathus stercoreus* and *Coprinus* spp., amongst others. Fungal species which remove lignin from the lignocellulosic complex faster than cellulose or hemicelluloses might be useful for this treatment. Particularly, organisms having negligible cellulolytic, but high ligninolytic activity, are ideal. Efforts in this direction have led to production and isolation of cellulase lacking (cel^-) strains of *P. chrysosporium* (Kirk *et al.*, 1986). However, early cel^- strain required longer time for lignin degradation, since these strains had very low phenol oxidase (POx) activity. As phenol oxidase activity is equally important in lignin degradation, Eriksson and Johnsrud (1983) developed mutant variants, which in addition to being cel^- were POx^+. Eriksson and Goodell (1974) reported that in *Polyporus adustus*, a single common regulator gene controls the induction of three enzymes viz., cellulase, xylanase and mannase. Thus in the wild type, all three activities exist, but in cel^- strain, other two activities also do not exist. Cel^- mutant of P. adustus reduced lignin content by 17% without destroying much cellulose. However, no digestibility and DM intake studies have been reported.

For enriching crop residues with microbial protein and also increasing their digestibility, SSF is found attractive (Laukevics *et al.*, 1984). Various fungal species namely *Pleurotus*, *Sclerotium*, *Coprinus*, *Sporotrichum pulverulentum*, *Trichoderma lignorum*, *T. harzianum* etc. have been probed in this respect. Gupta *et al.* (1993) reviewed the microbial conversion of cereal straws as ruminant feed including the use of enzymes. Alkalophilic fungal systems are particularly efficient among various treatments preceding SSF. Alkali treatment is effective in causing extensive swelling and separation of structural elements of lignocellulosic complex. Ammonia treatment of straw has also been reported to be moderately effective, but also adds nitrogen to the straw in addition to increasing digestibility of the straw. Recently, Gupta and co-workers proposed a concept of ammonia-trapping by an alkalophilic fungus, *Coprinus fimetarius* during SSF by the two-stage Karnal process, wherein microbiological treatment following urea treatment resulted in an increased crude protein content of the straw (Gupta, 1988; Gupta *et al.*, 1993).

Conversion into fuel ethanol

Lignocellulosic agricultural wastes have potential for conversion to fuel ethanol because of their sizable carbohydrate component. Broadly, the process involves delignification and subsequent hydrolytic release of fermentable sugars followed by anaerobic fermentation to ethanol. Some physical and chemical treatments are efficient in delignification and favour cellulose swelling, whereas certain ligninolytic fungal species such as *Poria monticola* and other brown rot fungi have also been used for delignification. Acid hydrolysis of native cellulose is a simple way of conversion to glucose. However, depending on the acid concentration and temperature for hydrolysis, glucose is further degraded to undesirable by-products, more so at enhanced rate of hydrolysis. This problem could be overcome by using enzymic hydrolysis instead of acid hydrolysis.

For economic production of ethanol, high cellulase producing microbial species are desirable in view of the high cost of cellulase. Among several fungal strains that have been tested in this regard, *Trichoderma reesei* and *Sporotrichum pulverulentum* hold promise. Though adoption of immobilized enzyme is beneficial in terms of recovery and reuse of the enzyme, it is unpractical to have a single fixed support in view of the heterogenity of the enzyme complex and their synergy, ultrafiltration may prevent cellulase inhibition by elimination of glucose through membrane, while permitting enzymic hydrolysis on the other side of the membrane (Sundstrom *et al.*, 1981).

In spite of differences in hydrolytic and fermentation conditions, simultaneous saccharification and alcoholic fermentation appears attainable by adopting co-cultures of cellulolytic and ethanol producing microbes such as *T. reesei* QM 9414 cellulase and *Saccharomyces cerevisiae* SK; *T. reesei* and *Candida brassica*; *Clostridium thermocellum* and *Zymomonas mobilis* Z2. Genetic improvement to narrow the gap in optimal temperatures for these steps is however, necessary. Certain fungal species such as *Fusarium* sp., and *Neurospora crassa* efficiently converts cellulose to ethanol. Among cellulolytic enzymes ß-glucosidase activity is crucial in ethanol production. By adjusting its activity to optimum level at the beginning of fermentation, cellulose conversion time can be markedly decreased. Apparently, there is a cellulase activity threshold supplying B-glucosidase with cellobiose, at a rate which under certain level of B-glucosidase activity satisfies the glucose requirement of fermenting cells (Christakopoulos *et al.*, 1990).

Pentosans constitute a substantial fraction of hemicelluloses, on hydrolysis, a sizable amount of pentoses are obtained from pentosans. These sugars, too should be converted to ethanol to improve the economics of such process. Although, pentoses are difficult to be assimilated and fermented by micro-organism, certain fungi, bacteria and yeast convert pentoses to ethanol. Its biochemical pathway is different in bacteria than those found in yeast and fungi. While xylose is converted to xylulose via xylose isomerase in the bacterial system, it is converted to xylulose-5-PO_4 via oxidative/reductive steps.

Several yeast genera, such as *Candida*, *Hansenula*, *Kluyveromyces*, *Pachysolen*, *Torulaspora*, *Brettanomyces*, *Schizosaccharomyces* etc., are best producers of ethanol from xylose. The most promising yeast strain in this regard is *Candida shehatae*, which produces 24.0 g l^{-1} ethanol, with only 0.2 g l^{-1} of xylitol, which inhibits xylose isomerase.

During the past decade, several approaches have been made to genetically construct pentose fermenting organisms by increasing the number of chromosomes. Skoog and Hahn-magerdal (1988) reported increased ethanol production coupled with reduced xylitol formation in *P. tannophilus*. In another approach, *E. coli* xylose isomerase gene was cloned in *S. cerevisiae* and also in *Schizosaccharomyces pombe*. However, despite this new gene, the limiting step in the xylose fermentation was its conversion to xylulose. Possibly, a mutant with xylose reductase, may overcome this limitation. Lee *et al.* (1986) induced mutations in *P. tannophilus* by UV irradiation and observed improved yield.

The production of ethanol from lignocellulosic agricultural wastes involves simultaneous enzymic hydrolysis of holocelluloses into constituent monosugars including glucose, xylose, xylobiose, triose, tetraose, pentoses and arabinose and their subsequent concomitant fermentation to ethanol. The complexity of multienzyme systems involved while attaining optimal conditions for maximum yield of alcohol would constrain the use of isolated enzymes for this purpose. Cellulases are adaptive enzymes. Multiplicity of such enzyme(s) may imply that when cultured on cellulose, pseudoxylanase activity is produced. *Neurospora crassa* NCIM 870 has been recently reported to produce extracellular cellulase complex, and has the capacity to convert cellulose to ethanol. It also produces xylanase even on cellulose as carbon source. Deshpande *et al.* (1986) reported direct fermentation of hemicelluloses and cellulose into ethanol by this organism. A mutant strain of *Bacillus stearothermophilus* LLD 15 can make ethanol from sucrose at 70°C and offers potential for novel fermentation processes at high temperature, with high yield and broad substrate range (Hartley and Shama, 1987).

Other uses of lignocellulosic wastes

Large quantities of lignocellulosic wastes are used through biological processes or other technologies viz., chemical hydrolysis, thermochemical conversion, catalytic liquefaction, pulping, combustion and reconstitution (Coombs, 1987; Hartley *et al.*, 1987). At present, the greatest volume of such wastes is cycled back to CO_2 through either natural decay or combustion. The main form of natural decay is the composting of wastes which is important in maintenance of soil fertility. Composting involves the decomposition of heterogeneous organic waste material by a mixed microbial population in a moist, warm aerobic environment into a stabilized humus like product (De Bertolds *et al.*, 1985).

Large amounts of lignocellulosic crop residues are used as feed for ruminants as discussed during this workshop. Their breakdown during anaerobic ruminant digestion depends on the activity of a complex consortium of anaerobic bacteria and protozoa. Similar bacteria are involved in the early stages of their degradation in both landfill and anaerobic digestors.

Mushroom cultivation is the economically most successful method for bioprocessing lignocelluloses and many commercial systems operate throughout the world. (Zadrazil and Grabbe, 1983; Hayes, 1985; Zadrazil, 1987).

Research has been carried out on alternative methods of gasification and catalytic liquefaction, at present direct combustion remains the major method used for lignocellulosic wastes with a water content of less than 40-45% (Pfeffer, 1988).

Other non-biological processes are reconstitution of sawdust and chips to form artificial boards and the chemical pulping of lignocellulosic materials in paper production (Coombs, 1987).

CONCLUSIONS

Large quantities of lignocellulosic residues and wastes are available which are presently either wasted, or processed through conventional biological and non-biological processes. Technological approaches for the utilization of straw by microbial systems have shown promise for the recovery of value added products such as food (mushrooms), feed and other chemicals having industrial application.

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SESSION FOUR

TREATMENT OF STRAWS

AND FIELD APPLICATIONS

TREATMENT OF STRAWS AND FIELD APPLICATIONS

Straws are known to be of low nutritive quality because they are mature plant parts. Also, since agronomic practices and plant breeding are aimed at transfer of as much as possible nutrients from the stem to the grain or pulse, only little nutrients are left in the stem.

The low nutritive quality of straw can be overcome by:
- *supplementation with limiting nutrients,*
- *improvement of the straw quality by treatment, management or breeding.*

The need for treatment and/or supplements depends on economics, and economics depend on feed costs and price of produce, i.e. on the desired type and level of animal production. These differ between farming systems. For situations with a good market for milk it can be financially attractive to buy supplement. In remote areas, farmers and their animals have learned to live with poor quality feed. Often, they manage by letting the animals loose weight in the dry season, after which they can recuperate in the season with enough feed.

Supplementation with limiting nutrients can have two extreme objectives:

a) *catalytic supplementation:*
   Small amounts of nutrients in supplements can improve rumen function, thereby increasing digestibility and intake of the basal feed. The use of urea molasses lickblocks for this purpose is well known, and other examples are the use of small amounts of green leaves etc. This method is most applicable in situations where the "catalytic supplement" is cheap compared to other supplements (to be compared on price/nutrient basis), where straw is available in excess, and where the animal is not expected to produce much more than only maintenance.

b) *substitutional supplementation:*
   The name implies that supplements in this approach can be used even to substitute the basal ration of (poor quality) roughage, sometimes at the risk of decreased rumen function, as is the case in many urban dairies of India. The approach is useful where the straw is expensive compared to supplement, when the milk or meat price is remunerative and where the animals are expected to produce considerable amounts of milk or meat. In those conditions it makes more sense to supplement, or even replace the straw with cakes, brans, concentrates or green fodder, than to maximize the proportion of straw in the ration.

Improvement of straw quality can be achieved in several ways and reduces the need for supplementation, depending on the production level of the animal. Different ways to improve straw quality are discussed in the paper of Sharma et al., *and include:*
- *treatment with chemicals,*
- *treatment with heat or steam,*

- *chopping, soaking or densification,*
- *other methods of harvesting, fertilization or choosing other grain varieties.*

Urea is the only practical chemical to date for (chemical) treatment of straw in rural tropical conditions. Methods to treat wheat and rice straw are well established but the applicability differs between farming systems and seasons. The paper of Rai et al. *explains how even between large and small farmers within one agro-ecological area there may exist differences in duration of treatment or type of stacking.*

The economics of straw treatment are discussed by Kumar et al. *They explain that economics may be difficult to calculate but there is a general agreement that treatment pays mainly where:*
- *urea and water are available;*
- *straw is cheap compared with other feeds, because after treatment straw intake increases and replaces supplements;*
- *the animals respond by increasing production or where they already are producing reasonable amounts of milk or other saleable produce to pay for the expense of treatment.*

Straw treatment has some practical problems and advantages which are not easy to quantify in economic terms, and reasons for success and failure of straw treatment in the field are discussed in the papers of Singh et al.*, and for Bangladesh and Sri Lanka by Saadullah and Siriwardene.*

The most practical example of physical treatment is use of steam on sugarcane bagasse. It is practical, especially near sugarcane mills where excess steam is sometimes generated and where sometimes large stacks of bagasse remain unused. Chopping, soaking or densification of straws can be done for different purposes: to reduce wastage, to increase intake, to reduce selective consumption or to reduce volume. The quantification of these effects is not yet consistent and work on this area is continuing, also to determine the farming systems where the methods might be useful (Sharma et al.*).*

The occurrence of (ir)regular serious droughts makes it necessary to consider various strategies to face these feed scarcities. Some strategies and the use of straw treatment methods are discussed by Thole et al.

Other methods of harvesting, fertilizer application or choosing grain varieties is a relatively new area of work and was discussed elaborately in session 5 on "Variability".

Modelling is being applied to see how crop rotations affect the type of animals that can be kept as shown by Patil et al. *Modelling can also help to show whether the system requires primarily higher quantity or improved quality of straw, depending on the initial quality and quantity of the straw itself and on the availability of other feeds in the farming system. In areas for example where plenty good quality berseem, e.g. (Haryana, Punjab, UP) or oilseed cakes (cities) is available there is* *little need to improve straw quality. This issue is elaborated by De Wit* et al. *in session 5.*

It is common to generalize about straw, but for specific situations a distinction is to be made between straw types as done in the paper of Prasad et al. *They suggest to distinguish between coarse straws (millets, sorghum and maize) and slender straws (wheat, rice, barley, oats). Rice straw could even be considered as a separate category. Treatment with urea is well worked out with slender straws (wheat, rice, rye, barley), but still being researched for so-called coarse straws (sorghum and millets). Urea ammonia treatment of sugarcane tops is not very successful. The initial quality of the coarse straws is generally better than that of slender straws.*

RECOMMENDATIONS ON CHEMICAL, PHYSICAL TREATMENT OF FIBROUS CROP RESIDUES

Long term on-farm trials on feeding of urea-treated straw on milk production should be carried out to determine economic feasibility and practical (dis)advantages.

Strong extension linkages have to be developed to popularise urea-treatment of straw, only in farming systems where the technology is likely to be beneficial.

Further work on urea-ammonia treatment is to be done only on crop residues like fingermillet straw, sorghum and maize straw, sugar cane tops, dried grasses, etc.

Densification is a need (especially in India) where straw for emergency feeding is often to be transported over long distances. Work has to be initiated in association with economists and agricultural engineers to determine economic feasibility and suitable methods of densification in the form of briquettes, blocks or wafers of bulky fibrous crop residues.

Work on physical treatment of crop residues and standardization of processing techniques for commercial production of complete feeds utilizing locally available crop residues and agro-industrial by-products should be undertaken, together with studies on the feasibility of these technologies.

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PHYSICAL AND CHEMICAL TREATMENT OF FIBROUS CROP RESIDUES TO IMPROVE NUTRITIVE VALUE - A REVIEW

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SUMMARY

Numerous efforts have been made to improve the nutritive value of fibrous crop residues by chemical and physical methods, but only a few attempts have been recorded that introduced such treatments effectively in the field. This paper reviews work with various treatment methods such as research on chemical treatment of various crop residues; the influence of physical treatments such as chopping, grinding, pelleting and the densification of fibrous residues on feed intake, nutrient digestibility and productive traits in ruminants. The recent trends in India of combining treated crop residues and unconventional agro-industrial by-products into densified blocks for economical transportation and effective utilization have also been discussed, together with some notes on feasibility of such technologies and their response on the animal under various socio-economic conditions.

INTRODUCTION

Fibrous crop residues have been used as ruminant feeds throughout the ages. The residues are low in readily available energy, nitrogen, minerals and vitamins and do provide inadequate amounts of nutrients even to maintain the animal body because of their low intake and digestibility (Singh and Oosting, 1993). Animal nutritionists, therefore in India and elsewhere attempt to improve the intake and digestibility through various methods like physical, chemical, physico-chemical treatments (Ibrahim, 1983; Sundstol and Owen, 1984; Doyle and Pearce, 1985; Owen and Jayasuriya, 1989). This paper reviews the present status of research on treatments of fibrous crop residues besides discussing briefly the possibilities for field application. Other papers in this session and elaborate the problems of application at greater length. The fifth session discusses the possibilities to improve straw quality and quantity through plant breeding and management.

SCOPE OF IMPROVEMENT THROUGH TREATMENTS

Roughages require adequate energy, protein and mineral supplementation in order to be degraded efficiently by microflora

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in the rumen (Walli *et al.*, 1993; Singh *et al.*, 1993). Since straws and other crop residues are short in both nitrogen and available energy, their improvement as animal feed can be achieved through treatments such as supplementation of nutrients at the time of feeding or the combination of treatment and supplementation.

WATER SOAKING

The effect of soaking on straw quality is not clear. Water soaking is assumed to affect the internal physico-chemical characteristics of the straw through swelling of the fibre, softening of particles, loosening the linkages within structural carbohydrates and ultimately on palatability. Chaturvedi *et al.* (1973) reported small increases of straw consumption in cattle and in buffaloes due to soaking of wheat straw with water (Table 1). Badurdeen *et al.* (1986) reported a non-significant increase in OMI, OMD and digestible OMI from 2.11 to 2.18 kg/100 kg BW, 47.28 to 49.61 % and 0.99 to 1.08 kg/100 kg BW due to wetting of rice straw. Mathur and Sharma (1985) reported that animals receiving water soaked wheat straw consumed appreciably more straw DM (2.9%) than unsoaked (2.6%) if straw is soaked 10 to 12 hr before feeding. Water soaked wheat straw based diet had significantly higher ADF and NFE digestibility than unsoaked wheat straw (Table 2). However, intake in both diets was unaffected (Singhal and Mudgal, 1980; Badurdeen *et al.*, 1986). Ranjhan (1981) reported that soaking of straw overnight before feeding improved intake as well as digestibility by 5 units.

Table 1 Effect of soaking of wheat straw.

Species	Feed	Body weight (kg)	Feed intake (kg/100 kg BW)
Cattle	Dry straw	299	1.98
Cattle	Soaked straw	315	2.18
Buffalo	Dry straw	288	2.03
Buffalo	Soaked straw	312	2.12

Table 2 Intake and nutrients digestibility on soaked wheat straw based diet.

Parameters	Unsoaked straw	Water soaked straw	Alkali soaked straw
DMI/100 kg BW(kg)	2.01	2.11	2.10
Digestibility (%)			
DM	52.2	55.8	57.6
ADF	40.8	45.3	46.4
NFE	70.8	80.1	79.4

CHOPPING

Physical treatment affects the ultrastructural make up of fibrous material such as straw, stovers and bagasse. Intake is influenced among others by the physical form and chemical composition of the feed (Ketelaars and Tolkamp, 1992). Chopping and grinding reduce particle size though the final particle size after chopping varies considerably. Haenlein and Holdren (1965) indicated that chopping increased digestibility. However, DMI and rate of passage of liquid digesta were not affected by chopping of oat straw (Singhal *et al.*, 1993). Feeding of chopped or long straw did not affect DMI (50 vs 51 g/kg $W^{0.75}$) and digestibility (41 vs 46%) in sheep (Devendra, 1983) but consumption of chopped rice straw was found higher (67 g) than of long straw (63g/kg $W^{0.75}$) (Castillo *et al.* (1982). Increased *in vitro* digestibilities by physical separation of cell wall components is possible by extreme reduction in particle size through ball milling (Millet *et al.*, 1970). The effect of grinding on intake is inversely proportional to the quality of roughage, the intake being more in case of crop residues compared to dried grasses. These effects may result due to increased rate of passage as well as better fermentation in the rumen (Van der Honing, 1975; Sundstol and Owen, 1984).

A major aim of chopping in farmers conditions may be to reduce the wastage (Doyle *et al.*, 1986), also reducing possibilities for selective consumption (Wahed *et al.*, 1990; Zemmelink, 1986; Subba Rao *et al.*, 1988). The fact that chopping is not practiced at all in Indian or Asian farming systems might be related to conditions of feed supply and desired level of animal production as discussed in this workshop by De Wit *et al.* (1993).

GRINDING AND PELLETING

Grinding and pelleting increase voluntary intake, but frequently depress digestibility (Minson, 1963; Donefer, 1972; Greenhalgh and Wainman, 1972). Stevens (1981) summarised that pelleting of low grade roughage type ingredients improves uniformity, density, dustiness, ease of handling and reduces wastage. Blaxter and Graham (1956) reported that grinding and pelleting increased faecal energy losses, but this has been compensated by lower losses of energy as heat and methane with no significant effect on net energy as a result of processing. Except for the decrease in digestibility of crude fibre, the effect of grinding and pelleting on utilization of other constituents appeared to be significantly higher (Labuda *et al.*, 1979). Rodrigue and Allen (1960) also observed that the finer the grind, the more rapid is the rate of passage and greater the depression in DMD, compensated by higher intake. Flachowsky *et al.* (1980) reported that the level of straw in pellets should not exceed 50% for beef cattle since beef cattle need more available energy. Eliseen *et al.* (1982) found that digestibility of nutrients and the utilization of nitrogen decreased with increasing straw in the diet.

STEAM TREATMENT

Steam treatment of low quality roughages has been reported to increase voluntary intake and digestibility in cattle by degradation of cellulose and hemicellulose, though associated with the production of undesirable poly-phenolic compounds in bagasse (Wayman *et al.*, 1972). Under laboratory conditions the effect of steam under pressure on fibrous residues was often successful (Klopfenstein and Bolsen, 1971; Bender *et al.*, 1970; Phoenix *et al.*, 1974; Oji and Mowat, 1978). Corn cobs and wheat straw showed continuous improvement in DMD as pressure was increased from 10-21 kg/cm^2 but DMD of milo stubbles showed no further response after an initial increase at 7 kg/cm^2 (Klopfenstein and Bolsen, 1971). Hart *et al.* (1975) studied steam treatment of rice straw and sugarcane products. The main effect of these treatments seemed to be the increase of water soluble straw components. Campbell *et al.* (1973) indicated higher digestibility of steam treated bagasse in lambs. Rangnekar *et al.* (1982) found a large decrease in hemicellulose and increase in VFA and IVDMD as effect of steam pressure treatment on sugarcane bagasse, paddy and sorghum straw at low pressures (5,7 and 9 kg/cm^2) for treatment periods of (30 and 60 minutes). Intake of steam treated maize stover was significantly higher (5.22 kg/d) than untreated (4.73 kg/d) without differences in weight gain but incurring higher cost due to increased intake. Results by Joshi *et al.* (1984) with cross-bred calves showed an increase in DMI of 16% over untreated.

With straw and bagasse, the improvements due to steam processing are generally either equal to or less than the effect produced by sodium hydroxide. It has been demonstrated that, at any temperature and steam pressure, there is an optimum treatment time above which the digestibility decreases (Martin *et al.*, 1974; Hart *et al.*, 1975; Ibrahim and Pearce, 1983). This may be due to over-treatment leading to burning or charring of material, or losses of (hemi)cellulose. The process is possible at centralized processing plants where steam is available and the process is actually in vogue in a few sugarcane factories of Gujarat where steam treatment is practiced without undergoing chemical treatment. The DM loss of 2 - 3% is marginal (Rangnekar *et al.*, 1986).

IRRADIATION

Improvement of digestibility of wheat straw was achieved by use of X-rays, which cause breakage of the cellulose and hemicellulose bonds, resulting in formation of oligosaccharides, which can be utilized by the rumen organisms. Forage lignin on the other hand can resist irradiation. Irradiation, yields calciferol in dry fodders, commonly known as vitamin D_2 from ergosterol, a plant sterol (Banerjee, 1988). Gamma irradiation has been reported to improve the digestibility of carbohydrates of straw and other residues by rumen microbes (Pritchard *et al.*, 1962; Millet *et al.*, 1970; Huffman *et al.*, 1971; Ibrahim and Pearce, 1983). However, high irradiation dosages are needed before significant increases in digestibility can be obtained. The process involves high cost and technology and is therefore not likely to be relevant for field conditions.

ALKALI TREATMENT

In the past the most widely applied chemical which produced good results particularly for large scale treatment, was sodium hydroxide (Sundstøl and Owen, 1984; Lampila 1963; Wilson and Pigden, 1964). However, the use of sodium hydroxide on small farms at village level was uneconomical and slightly dangerous. The use of ammonium hydroxide attracted the researchers because it increases the nitrogen content, in addition to the digestibility and intake of straw. Because of the requirement of special equipment for transport and application of liquid and anhydrous ammonia, the use of ammonia is not feasible under small farm conditions in a country like India. Another cheap alkali (calcium hydroxide) was tried but due to its low solubility, imbalance in Ca : P ratio and being a weak alkali, it has not been found to be very effective for *in vivo* animal performance.

In tropical climates, urea has been found to be the most suitable source of ammonia for treating straws to increase feeding value because of its ready availability, familiarity of farmers with its transport, storage and application in addition to its good effect on intake, digestibility, growth and milk production. Different methods can be applied to treat straw with urea (Rai *et al.*, 1993). Oji and Mowat (1978) put damp maize stover and added urea in a conventional silo. After stacking, the straw was sprayed with 4 kg urea/100 kg straw dissolved in a suitable quantity of water to have 45 - 50% moisture content and stored for a variable period which is a usual practice. Consumption of straw treated with the wet method of NaOH was low in comparison to straw treated with the dry method of NaOH or NH_3 (Garmo and Arnason, 1980) for treated barley straw (see Table 3) when fed with grass silage and concentrate.

Wanapat *et al.* (1983) reported a lower digestibility of straw treated with aqueous comparison of wet and dry method NH_3 than anhydrous NH_3 (see Table 4). Ibrahim (1985) indicated (see Table 5) that higher level or urea (ammonia) reduced the OMD, DMI and LWG.

Major factors affecting the degree of improvement of nutritive value of straw are the level of urea, treatment temperature, curing period, moisture content, structure used and type of straw. Saadullah *et al.* (1981a, b) reported that 5% urea level

Table 3 Dry matter intake of treated straw (kg DM/animal/day) and bulk production (4% FCM, kg/day).

Parameters	Experiment-I			Experiment-II		
	1	2	3	1	2	3
Silage (kg DMI/d)	4.3	4.3	4.3	4.1	4.1	4.1
Straw (kg DMI/d)	3.3	3.9	3.8	2.9	3.7	3.5
Concentrate (kg DM/d)	6.4	6.8	6.6	7.9	7.9	8.1
4% FCM (kg/d)	18.2	19.4	18.4	19.8	19.3	19.0

Note: 1 NaOH (Wet method) - DOM in Sheep 74%
2 NaOH (Dry method) - DOM in Sheep 70%
3 NH_3 (Dry method) - DOM in Sheep 61%

Table 4 Digestibility of treated straw.

Parameters	Digestibility %			
	DM	OM	CF	Energy
Aqueous NH_3	57.2	59.0	71.4	59.3
Anhydrous-NH_3	65.7	67.8	79.0	69.0

Table 5 Effect of level of urea on intake and digestibility of treated straw.

Parameters	Untreated straw	Level of urea	
		4%	6%
Organic matter digestibility	52	57	55
Dry matter intake (kg/100 kg BW)	2.0	2.8	2.7
LWG (g/animal/day)	-132	119	75

was more effective than 3% for rice straw. The effect of ammoniation is accelerated by increasing temperature. Waagepetersen and Vestergaard (1977) observed in cold climates that the ambient temperature had a positive effect up to 45°C with 3 or 7 day period. Sundstol *et al.* (1978) observed that at an ambient temperature around or below freezing point the action of ammonia was very slow. This may not be useful for the tropics in India as long as the stack temperature is high enough. Singh and Negi (1985) treated wheat straw with 3.75% urea with 50% moisture in drums covered with lids and allowed 95 days for reaction at room temperature during the months of January - March and found DMI's of 551 and 553 g/d in mature rams on untreated and urea treated straw respectively. The DMD was 48 and 49 for untreated and treated straw, i.e. the differences were very low. They concluded that ammoniation by urea as a method of improving the nutritive value of low quality straw may not be very practical under field conditions in cold regions.

Perdok *et al.* (1982) observed that urea treatment of paddy straw (4%) ensiled in various containers has given good results in 28 days in polythene sheets. A period of 3-6 weeks, or even less would probably be adequate under diversified Indian conditions (Rai *et al.*, 1993). Waiss *et al.* (1972) found that an optimum moisture content was 30% when wheat straw was treated with aqueous ammonia at ambient temperature while Rashing (1980) reported maximum improvement in fermentability at a moisture content of 65%. Several structures have been used for treating straw with urea as a source of ammonia and they are reviewed by Rai *et al.* (1993). Saadullah *et al.* (1981a) used earthen pits and Bamboo baskets. The latter gave poor results whereas polythene gave good results (Perdok *et al.*, 1982). A traditional structure commonly used for storing wheat bhusa in western U.P. called *bonga* was found suitable by Pantnagar workers. Stacking of treated straw in animal shed, storage room, and *Varandah*, when covered suitably, are also common structures used for urea treatment.

Hossain and Rehman (1981) fed 5% urea treated straw to cross-bred calves with 1 kg green sorghum and concentrate with bone meal and common salt, DMD increased from 49 (untreated) to 63 and DMI from 2.6 (untreated) to 3.1 for untreated but urea supplemented rice straw. The treated straw provided 0.31 kg more DDM and produced an extra gain of about 60-80g/day on urea supplemented straw. Saadullah *et al.* (1981b) reported improved intake and weight gain on urea supplemented and urea treated rice straw (Table 6).

Table 6 Performance of calves on urea treated rice straw.

Particulars	Untreated rice straw	Urea Supp. rice straw	Urea treated rice straw
DMD (%)	40	46	51
DMI (kg/d)	1.7	1.7	1.9
ADG (g/d)	35	75	110
DDMI (calculated)	0.68	0.78	0.97

A decreased digestibility of treated straw as compared to untreated straw was observed by Prakash (1984) in case of maize stover and Jaiswal *et al.* (1983) in case of rice straw fed to cross-bred heifers. An increase of 5% in DMD in wheat straw was observed by Gadre (1979) due to urea treatment but Rashing (1980), Saadullah *et al.* (1981a), and Djajanegara *et al.* (1983) also reported a decreased DMD. More than 10% digestibility increase was reported by Saadullah *et al.* (1981b), Wanapat *et al.* (1983), Hossain and Rehman (1981). An overall analysis of changes in digestibility of urea treated straw indicated that it was affected by type of straw, type and amount of supplement as well as the DMI. In general the DMI increased beyond 80-90 $g/kg^{0.75}$ BW.

A 2-10% increase in DMI due to feeding urea treated straw was reported by Hamid *et al.* (1983), in growing calves with daily supplement of 1 kg green grass and fish meal and by Haque and

Saadullah (1983) and Prakash (1984) in growing cross-bred heifers receiving a supplement of green berseem and cotton seed cake. A high intake in the range of 10% to 20% was reported by Hossain and Rehman (1981), Saadullah *et al.* (1981b), Jaiswal *et al.* (1983) in lactating cross-bred cows. More than a 20% increase of DMI was reported by Gadre (1979), Jayasuriya and Perera (1982), Khan and Davis (1982), Jaiswal *et al.* (1983),

The increase in growth rate in cattle fed on urea treated straw varied less than 100 g/d (Dolberg *et al.*, 1981; Kumarasuntharam *et al.*, 1984), between 100-400 g/d by Khan and Davis (1982), Jaiswal *et al.* (1983), Prakash (1984), and above 400 g/d by Wongsrikeao and Wanapat (1985) and Wanapat *et al.* (1984). Studies carried out on the feeding of urea treated straw indicated that without concentrate or green supplementation treated straw can support a growth rate of 7-318 g/d depending on the type of animal and level of intake of treated straw and type of supplement. Normally one should not expect more than 100-150 g/d extra growth due to feeding of urea treated straw but few studies like that of Wanapat *et al.* (1984) in buffaloes and Perdok *et al.* (1984) in growing Sahiwal cattle showed an increase of body weight of 210 and 318 g/d, respectively, due to feeding of treated straw.

An increase of 0.15 to 1.5 kg in milk production has been reported by Khan and Davis (1981), and Perdok *et al.* (1982, 1984). Additional small supplementation of 200 g oil cake/kg milk produced increase in milk from 0.6 (untreated) to 2.1 kg (treated straw)/d (Khan and Davis, 1982). Cross-bred cows produced more than the local breed. Such an increase was 41% more in Gir cow than 37% in Surti buffaloes. It indicates that the change in milk production was not more than 1.5 kg/animal/day. Animals were losing body weight on untreated straw but urea treated straw had a better effect.

Treatment with oxidizing agents

Oxidizing reactions cause lignin solubilization and therefore improve straw quality. Chandra and Jackson (1971) while treating maize cobs with various chemicals found that oxidizing compounds appeared to have some potential for improving the nutritive value of crop residues. Bleaching powder was equally effective as sodium hydroxide in removing or solubilizing lignin but at higher levels the residual chlorine in treated material may have been toxic to rumen micro-organisms and thus (*in vivo*) digestion inhibited beyond 2% level of treatment. Sodium sulphide was slightly more effective than sodium sulphite to break up lignin of cobs probably due to production of sodium hydroxide in the reaction. A similar pattern or effect was recorded by Owen *et al.* (1977). Lignin was lower in sodium sulphite treated wheat straw but cellulose and rumen degradable DM was again higher due to sodium hydroxide treatment (Kundu and Mudgal, 1985).

A trial where wheat straw was treated with oxidizing chemicals such as bleaching powder, sodium hypochlorite, sodium sulphite and sodium thiosulphate at four levels (1, 2, 3 and 4%) indicated that bleaching powder treatment had no effect on IVDMD nor NBDMD, however, sodium thiosulphate had a negative effect (Kundu and Sharma, 1991). Sodium hypochlorite increased NBDMD from 48% in control to 67% at 3% level, but *in vitro* DMD increased by 47%. A one month reaction period showed maximum improvement in degradability compared to 3 months reaction period. An alkaline pH was found more effective to dissolve cell wall constituents for increased IVDMD and NBDMD. Yu *et al.* (1975) found increased digestibility (9 units) of sodium chlorite treated straw-based diet but the intake was hardly one third of the untreated straw-based diet. However, the intake increased after washing the sodium chlorite treated straw. The DMI by buffalo calves was high on bleaching powder (2%) + sodium hydroxide (1%) treated (6.87 kg) units followed by sodium hydroxide (1%) treated (6.32 kg) and untreated (5.65 kg) straw groups (Kundu and Sharma, 1991). DOMI increased from 764 g/100 kg BW in control to 916 g/100 kg BW in sodium hydroxide and 947 g/100 kg BW in bleaching powder treated groups. It was also reported by these workers that daily weight gain (338 g/d), feed conversion efficiency (9.87 kg) and feed cost per kg weight gain (INR 11.89) were higher on alkali treated straw than on straw treated with bleaching powder groups.

COMPLETE FEEDS WITH FIBROUS CROP RESIDUES

In this approach, feed ingredients inclusive of (un)treated crop residues are mixed into a uniform blend constituting complete feed. This technique combines chemical and physical processing of crop residues with proper supplements to provide a stable environment for rumen fermentation, to minimise fermentation losses, to minimize fluctuation in release of ammonia, to stabilize the acetate to propionate ratio which favours normal butter fat synthesis, and to enhance utilization of low grade roughages since protein and energy from other feed ingredients is closely attached to roughage feed particles (Sharma and Singhal, 1988). Linnik (1982) observed that complete feed mixtures containing 65 to 70% straw were efficiently utilized in cattle either fed pelleted or loose straw. Eliseen *et al.* (1982) found that digestibility of nutrients and the utilization of nitrogen decreased with increasing straw in the complete diets. Lohnert *et al.* (1983) observed that there was a negative correlation between the percentage of straw (upto 50%) inmash or pellets and the digestibility. Khokhar *et al.* (1985) observed that alkali treated straw in complete feeds significantly increased DM consumption by growing calves, however, the effect of pelleting was non-significant. Complete diets containing 45% cotton straw or 47% mixed grass hay or 35% sunflower straw maintained milk production of 6 to 8 litres with normal butter fat compared to conventional type feed containing mixed grass hay, hybrid napier grass and concentrate mixture (Reddy, 1990). Rathee and Lohan (1982) reported that pelleting of complete feed increased DMI but that it depressed the DMD and ADFD. Soni and Sharma (1982) prepared complete feeds with or without urea where pelleting reduced *in vitro* nitrogen solubility and release of ammonia-N.

DENSIFICATION OF CROP RESIDUES

Crop residues are bulky and difficult to transport from surplus to scarcity regions of the country as discussed by Thole *et al.* (1993). Recently efforts have been made to densify the crop residues or complete feeds containing crop residues into pellets, cubes, briquettes and blocks. Sah *et al.* (1981) studied the compaction behaviour of ground wheat straw. They observed that to obtain density ratio beyond 2.5 the load and power tremendously increased. The densification of feeds to wafers also depend on pressure applied, moisture content and plant characteristics (Singh *et al.*, 1986).

Kundu and Sharma (1991) densified compounded complete feeds containing 67 to 75% wheat straw that was either untreated, or treated with alkali or bleaching powder, into feed blocks. Blocks with a lower level of straw were more compact (density 0.53 g/cm^3), and a pressure of 80 to 110 kg/cm^2 for 3 minutes appeared best for setting the feed mass into blocks. Moisture levels of 17-18% resulted in compact blocks with untreated straw and moisture level higher than 20% resulted in a loose block. Alkali treated straw blocks were more compact (density 0.47 g/cm^3) than untreated straw (density 0.36 g/cm^3) and inclusion of 10% molasses produced optimum texture. The increase in density was 3.91 and 3.83 times for blocks made of treated straw having concentrate ingredients alongwith 23 and 18% moisture, respectively, compared with undensified material.

A relatively higher increase in bulk density (Kumar, 1988) by compaction was reported in paddy straw compared to wheat straw and in unground straw compared to ground straw. In paddy straw the expansion was significantly lower and durability of texture higher than wheat straw based feed blocks. The unground form of both the straws resulted in higher expansion and lower durability. DM, CF and NFE digestibilities were higher in paddy straw than in wheat straw based feed blocks and also higher in unground than in the ground form of the respective straws. Alkali treatment of straw increased bulk density and compactness of complete feed blocks (Singh, 1989). DM, NDF and ADF digestibilities were significantly higher in alkali treated straw based feed blocks than in untreated, straw, due to compression and/or alkali treatment. Singh (1989) reported a higher durability and a lower post compression expansion in alkali treated straw based blocks than in untreated straw. They found higher durability, when 20% molasses was included. Both durability and expansion were increased with pressure applied. The increase in bulk density by compaction was reported (Singh, 1989) 3.19 and 3.83 times for untreated and sodium hydroxide treated wheat straw based blocks, respectively. Kumar (1988) reported that urea treatment had no effect on compaction characteristics of paddy straw compared to sodium hydroxide and sulphuric acid treatment but a combination of cooked barley flour and heated molasses acted as a suitable binder compared to non-heated barley and molasses. Treatment of straw combined with compaction will have an added effect for efficient management of using low density feed stuffs for animal production.

CONCLUSIONS

Variable responses to treatment in terms of digestibility, DMI, growth and milk production are either due to treatment/animal factor or both. Within treatments, the variable effect may be caused by type of straw and its variety, level of urea, moisture, CP value of treated straw, curing period, structure for stacking and storage time. Animal factors include type and physiological status of the animal.

Particle size not only reflects upon intake but also on digestibility and rate of feed passage. The finer the grind, the more rapid is the rate of passage which is simultanously compensated with higher intake. Pelleting also improves intake and checks losses due to handling alkali treated straw achieves higher improvement, but urea as well as some of the oxidizing agents are more promising and economical.

In addition to the type and amount of supplement, the proportion of treated straw in the different diets also are most important. Densification of straw after proper chemical treatment reduces cost of transport and provides additional and uniform nutrition if compounded into complete feeds. None of the treatments can be seen in isolation from supplementation of which the production of complete feeds is a special case. Densification of feeds is attempted and especially relevant where bulky roughages need be transported over long distances.

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REASONS FOR SUCCESS AND FAILURE OF STRAW TREATMENT AND STRAW FEEDING IN BANGLADESH AND SRI LANKA

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SUMMARY

This paper gives background information with regard to the characteristics of farming systems in Bangladesh and Sri Lanka, the feeding practices and the utilisation of crop residues, particularly of rice straw as a means of meeting the feed deficit during periods of roughage scarcity. Rice straw has different uses but traditionally it has been used as a important feed. The application of new technologies to improve the utilisation of this resource under local conditions and the experiences and responses in terms of animal production are discussed. The paper highlights the reasons for the success and failure of the use of rice straw as a ruminant feed and the farmer opinions with respect to the applicability of the new technology for utilisation of rice straw.

INTRODUCTION

Both in Bangladesh and Sri Lanka, as in other Asian countries, cattle and buffaloes form an essential component of the farming system. They supply the major part of the draught power for land preparation, for transport, for threshing of grain and for crushing of sugar-cane and oilseeds. Cattle and buffaloes are also an important source of milk and in some areas they are reared solely for milk production purposes. Additionally, they provide meat for human consumption and of hides and skins, and bones and horns which are raw materials for industrial purposes. Animal manure is an important source of fuel for domestic use and of fertilizer for crop production. Livestock production by and large is a small farm enterprise which generally is secondary but a supportive activity in the farming systems. This paper discusses the experiences in Bangladesh and Sri Lanka about the feeding of urea ammonia treated straw related with the farming systems in those countries.

CHARACTERISTICS OF FARMING SYSTEMS IN BANGLADESH

Farmers in Bangladesh, maintain a pair of bullocks or cows as draught animals for their own use and also hire them out to neighbours. One or two milking cows, or goats and in some regions sheep are maintained for milk production and eventually for meat. It is a common practice to keep a few chickens and ducks for eggs and meat. Generally small ruminants and chickens are cared for

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by women and children. The types of farming systems that exist in Bangladesh are shown in Table 1.

Table 1 shows that 86.5% of farmers maintain livestock along with crops. Farmers engaged exclusively in crop production constitute only 3.5% of the total number of households. The average number of cattle per household is estimated to be 1.5 (mainly Zebu breeds) and that of buffaloes at 0.36. Between 60 - 65% of the cow population is used for draught purposes in Bangladesh. It has been reported that 77% of the land is utilized for rice production and the rest, inclusive of river beds, canal beds, land depression etc. for cultivation of jute, sugar-cane, pulses and tea (Jackson, 1980). Animals are highly dependent on crop residues such as straws for feed. No land is exclusively used for animal feed production. The ownership distribution of arable land in Bangladesh is shown in Table 2.

Table 1 Types of farms and sufficiency of cereal products

Type of farm	As percentage of total households			
	Deficit	Selfsufficient	Surplus	Total
Livestock/Poultry with crops	52.00	17.50	17.00	86.50
Crops only	2.50	-	1.00	3.50
Fish	4.00	2.50	0.50	7.00
No Enterprise	3.00	-	-	3.00
Total	61.50	20.00	18.50	100.00

Notes: (1) The specialized livestock component without crops (goats & poultry) constitutes 4%; (2) selfsufficiency means: selfsufficient in food

Table 2 Landownership in Bangladesh

% of population	Proportion of arable land
33	-
29	10
28	40
10	50

CHARACTERISTICS OF FARMING SYSTEMS IN SRI LANKA

The characteristics of the farming systems in Sri Lanka are shown in Table 3. Major differences exist between the main features in the systems in Sri Lanka and Bangladesh. Sri lanka has on an average more land per farming family, it is less dependent on rice production and more clearly defined in a few major agroclimatic zone, with different soil types and rainfall. Average income (i.e. purchasing power for milk) is also higher in Sri Lanka). Based on the systems of cattle and buffalo management and agro-climatic conditions, four main types of dairy management systems can be identified:

- the Hill Country System (HS),

- the Mid-Country Village System (MVS),
- the Coconut Triangle Village System (CTVS),
- the Dry Zone System (DZS).

In the Hill Country tea plantation sector, animals are zero-grazed and fed on naturally growing kikuyu grass found in ravines, waste land and road sides. Concentrates are fed to supplement the forage feed. Temperate breeds, mostly Friesian and Ayrshire and their crosses are maintained, producing between 10-12 litres per day. The problem in this region is the inadequacy of fodder to meet the fodder requirements of animals. Limitations of land for fodder cultivation results from intense competition for land for cultivation of other high income generating crops such as potato and vegetables. Fodder shortages generally occur during the (relatively short) dry period from January to mid-April. The area has little grain farming, hence straw is not important in that feeding system.

Table 3 Characteristics of farming systems in Sri Lanka

Features	HCS	MVS	CPS	DZS
Elevation (m)	1000	450-1000	100	90
Av. temperature (°C)	15	25	27	27
No. of months with less than 10 cm rainfal	2	1	2	7
Av. farm size (ha)	0.7	0.7	1.4	1.7
Predominant crops	Tea Vegetables	Vegetables Rice Coffee Spices	Rice Coconut Fruits	Rice Vegetables Cereal and other crops
Types of animals	Temperate	Temperate Cross-breds	Temp.X Zebu Cross-breds	Indigenous
Av. milk yield (l/animal/day)	10-12	5-8	4	2
Forage constraints	Continuous	Seasonal	Seasonal	Seasonal

Notes: HCS = Hill Country System; MVS = Mid-country Village System; CPS = Coconut Triangle Village System; DZS = Dry Zone System

In the Mid-Country Village System, cultivated pasture is scarce. Here again the animals are zero-grazed and fed on a local ecotype of Panicum maximum (Guinea grass). While adequate fodder is available during the wet months, feed shortages become a serious problem during dry months. Concentrate feeding is practised but the extent of supplementation with concentrates is a function of the price of feed as against the price received for milk. Coconut press cake as the preferred concentrate is generally more expensive during dry periods. More grain (rice) cropping is done but straw is difficult to collect and store dry due to uncertain weather conditions.

In the Coconut plantation area and the dry zone, the climatic effect on fodder availability is similar to that prevalent in the Mid-Country. The fodder availability during the prolonged dry periods is very low. Supplementation with concentrates is not economical because the low milk yields even from cross-bred stock do not adequately compensate additional financial inputs.

Fodder conservation is not practised in Sri Lanka for various reasons such as:

- conservation is possible only when there is surplus grass. Such a surplus is available only in the wet season, when the climatic conditions are not conducive for conservation practices. Problems of collection, drying or wilting and storage under unpredictable weather conditions make conservation difficult or impossible.
- dairying is a supplementary farming activity. Farmers give priority to cropping activities during the wet season. As they are not full-time dairy farmers, they do not consider time allocated to fodder conservation activities profitable.
- the sugar content of tropical grasses is low and not ideal for production of good quality silage. The use of additives is costly and not practicable under Sri Lanka conditions.
- fodder conservation involves harvesting and transport of fodder from places where surplus is available. This is generally distant from the homesteads or cattle sheds.
- facilities for proper storage are generally not sufficiently available to ensure maintenance of quality during storage. Farmers who experiment with feeding of conserved feeds do not often see the expected benefits of feeding conserved feeds in circumstances where there has been deterioration in quality during storage.
- the economic returns of engaging in conservation practices are not sufficiently remunerative where alternative opportunities exist for income generation during the wet season and the period immediately after the end of the wet season.

UTILIZATION OF CROP RESIDUES

One obvious solution to overcome the shortage of feed would be to supplement the forage with concentrate feed. But, the unfavourable price relationships between concentrates and the farm-gate milk price acts as a disincentive to the liberal use of concentrate feeds both in Bangladesh and Sri Lanka. It is therefore apparent that the only other alternative available is to maximize the utilization of crop residues and agro-industrial by-products to meet the deficit in feed requirements.

FEED RESOURCES AVAILABLE IN BANGLADESH AND SRI LANKA

The feed resources available for use as feed for ruminants in Bangladesh and Sri Lanka can be grouped as:

* agro-industrial by-products,
  - agricultural crop residues (straw, stover, sugar cane tops);
  - by-products from agro-industries (molasses, pineapple-waste, bagasse);
  - milling by-products (brans and oilseed cakes)

* green roughages,
  - cultivated grasses and legumes;
  - indigenous grasses from road-sides, waste-land and waterways;
  - leaves of forest and fruit trees

* animal and marine (by)products,
  - slaughterhouse by-products;
  - animal wastes (e.g. excreta);
  - marine by-products.

Information relating to most of the above feeds with regard to their availability, extent of utilization and nutritive value are scarce both in Bangladesh and Sri Lanka. A comprehensive inventory of this information together with information such as the seasonal variation in availability, production practices and possible toxic or deleterious contents will be necessary for proper planning of research and development in the future.

STRAW AS A FEED RESOURCE

Straw is by far the most important and most abundant of the crop residues available in both countries. This feed material constitutes about 90% of the feed available in Bangladesh (Jackson, 1980), and 54% in Sri Lanka (Siriwardene, 1985). Especially in Bangladesh this feed resource is not available in sufficient quantities to meet the feed requirements of farmers for year-round feeding. The total production of rice straw was about 16.9 million tonnes in 1983 - 1984 (BBS, 1984). Straw from other sources are not included in this estimate. Twenty percent of rice straw in Bangladesh is obtained between mid-July and mid-September, 44% between mid-November and mid-February and the balance in March and April (Tareque and Saadullah, 1988). If the straw from other cereal crops are taken into consideration, the total availability of straw would account for 38.4% of the total dry matter requirements for ruminant feeding in Bangladesh. That is very low indeed and can be explained because it excludes the residues from other crops, and large quantities of straw is used for fuel and house building materials.

It should however be noted that not all the straw available could be used exclusively as animal feed. Straw has other uses in Bangladesh (Table 4).

In Sri Lanka too, rice straw is utilized for other purposes than for animal feed, such as thatching of roofs, as source of fertilizer in rice fields, in paper manufacture and in packaging. But large quantities are left unutilized or are burned around threshing floors. Quantitative estimates of utilization are not available.

Tabel 4 Utilization of straw in Kanthal Union, Trishal (Bangladesh)

Uses	Percentage of total production in Bangladesh
Animal Feed	47
Fuel	14
House Building	10
Discarded due to spoilage and other uses	29

Source: Saadullah et al. (1991)

DEVELOPMENT OF TECHNOLOGY

The treatment of low quality roughages with ammonia derived from urea has been discussed and promoted extensively throughout South and South East Asia (Table 5), as also discussed in this workshop (Devendra, 1993).

Small groups of scientists in different regions of the tropics have contributed to the development of the technology, with or without foreign assistance. These workers have developed appropriate methods for treatment of materials available in their own situations. The efforts of such experimentation on-station as well as in on-farm situations have been presented at the conferences listed in Table 5. It is now opportune to examine the results and experiences at village level as regards, adaption, economic returns, problems confronted and to try to find solutions to the problems faced by the farmers. So far, there have been no reports of any bad or negative responses with livestock, and on farm trials as well as on station trials are also discussed in this workshop.

Table 5 Recent international workshops/seminars on feeding of crop residues and by-products in developing countries.

Venue	Sponsor	Year
Bangladesh	DANIDA	1980
Bangladesh	DANIDA/IDRC/ODA/ADAB	1981
Bangladesh	ODA/ADAB/DANIDA/USAID	1982
Malaysia	ADAB	1981
Philippines	ADAB	1983
Bangladesh	DANIDA/ADAB	1983
Sri Lanka	ADAB	1984
Thailand	ADAB	1985
Thailand	IFS	1985
Indonesia	ADAB	1986
Sri Lanka	The Netherlands	1986
Philippines	ADAB	1987
India	Indo/Dutch	1987
India	Indo/Dutch	1988

Source: Owen and Jayasuriya (1989)

Recognising the fact that cultivable land is not and will not be available for exclusive production of animal feed or fodder, a number of workshops on "Maximum Livestock Production from Minimum Land" were held in Bangladesh in the early eighties. The title of those workshops clearly indicates the importance assigned to increasing productivity with the available animal and feed resources, which are mainly crop residues and milling offal. This situation is basically not different in many developing countries such as Sri Lanka, Vietnam etc. The initial workshops focussed on the technology of urea treatment and supplementation. From approx 1985 onwards more attention was paid to practical and economical feasibility and an increasing number of onfarm trials were reported. By the end of the eighties/early nineties the technical problems of treatment are pretty well settled. More attention is now paid to supplementation and possibilities to improve straw quality/quantity by genetic means or management.

RESULTS OF FEEDING UREA TREATED STRAW AT ON-FARM TRIALS

The results from a number of farm experiments are presented in this report on the effectiveness of ammoniated rice straw on the milk production. The milk production of the cows on treated straw compared to that of the previous year when they were on untreated straw as reported by the farmers, have increased significantly (see Table 6), irrespective of the previous level of production (Saadullah *et al.*, 1988). The highest benefit from straw treatment was observed with cows producing up to 1 litre of milk per day before introduction of the technology. The lowest improvement of 45% was observed with the cows producing more than 2 litres in previous lactation, possibly because those cows already being relatively well fed. Table 7 compares the average milk production of the cows according to age, with no significant age related difference in milk production.

Table 6 Effects of feeding untreated and ammoniated rice straw to cows of different level of milk production (litre per day) in Maizdee.

Level of production (l/day)	Untreated		Ammoniated		Increase in percent
	No. of cows	Milk/day	No.of cows	Milk/day	
0.50 to 1.00	6	0.58	6	1.42	145
1.01 to 1.49	13	1.15	13	2.15	87
1.50 to 1.99	9	1.50	9	2.51	66
2.00 & above	15	2.05	15	2.97	45

Source: Saadullah et al. (1988)

The effect of lactation on milk production is shown in Table 8. The difference between 2nd and 4th lactations was found to be significant ($P < 0.05$) both for cows receiving treated as well as untreated straw. A project assisted by the Rotary Foundation

Table 7 Effect of age of the cows fed untreated and ammoniated rice straw on milk production (litre per day) in Noakhali.

Diet	Age of the cows (in years)		
	3	4	5 and above
Untreated	1.56 a	1.51 a	1.31 a
Ammoniated	2.41 b	2.50 b	2.30 b

Source: Saadullah et al. (1988)
Note: a & b: means bearing the same superscripts within same rows or column are not significantly different ($P < 0.01$).

Table 8 Effects of number of lactation of cows fed untreated and ammoniated rice straw on milk production (litre per day) in Noakhali.

Lactation no.	No. of cows	Dairy milk production per day	
		Untreated	Ammoniated
1st Lactation	3	-	2.40 d
2nd Lactation	25	1.51 a	2.53 d
3rd Lactation	9	1.31 a	2.28 cd
4th Lactation	6	1.35 ab	2.15 bc

Source: Saadullah et al. (1988).
Note: a, b, c & d: means bearing the same superscripts within same rows or column are not significantly different ($P < 0.05$)

Table 9 Milk yield of cows fed with untreated straw for 60 days after calving and the rest 90 days with urea treated straw under the normal feeding systems in Kanthal union, Trishal, Mymensing.

Lactation no.	No. of cows	No. of farmers	Milk yield 60 days (l/day)	Milk yield while feeding treated straw (litre per day)						Daily average milk yield (l/day)	
				74*	88*	102*	116*	130*	144*	before	after
First	5	5	0.70	0.80	1.00	1.20	1.40	1.40	1.50		
Second	17	17	0.60	0.80	0.94	1.10	1.20	1.36	1.54	0.76	1.26
Third	7	3	0.98	1.41	1.16	1.18	1.33	1.43	1.40		

Notes: taken 37.45 equivalent 1 vs $; numbers in fifth to tenth column refer to days on treated straw.

of Rotary International in collaboration with Rotary Club of Mymensingh and Bangladesh Agricultural University has been trying to improve the livestock productivity through health care and improved feeding practices for the last 3 years. Results from feeding urea treated straw to cows and marginal cost and benefit is shown in Table 10. These cows were in different stages of lactation. Daily milk yields of these cows were monitored for 60 days after calving. Normal feeding regime of the farmers was not disturbed (occasional grazing at road side/or supplementation with scanty amounts of collected grasses). After expiry of 60 days the cows were fed with treated straw within normal feeding systems for another period of 90 days to compare the milk yields before and after the adoption of technology. The average milk yield of cows increased by 65% from an average daily milk production of 0.76 litre to 1.26 litres. The net marginal gain in terms of money, subtracting the cost for treatment was calculated (see Table 9) to be Tk. 3.88 per day, in favour of treated straw, based on the farmers' memory.

Table 10 Calculation of costs and income from milk in Bangladesh

	TS	US	
Milk yield	1.26	0.76	
Income from milk	12 TK	7.5 TK	(1)
Cost of straw			
- Kg consumed	2.25	2.25	(2)
- TK/kg straw	1.00	1.00	(3)
- Total cost straw	2.25	2.25	(4)
Cost of urea	0.62	-	(5)
Marginal benefit	9.13	5.25	(1)-(4+5)

Notes: under (4), the cost for straw was estimated to be same; LW = average 95 to 115 kg.

Production performance from supplementing ammonia treated straw with various amounts and types of protein and energy rich feed fed to both small and large ruminants have been reported by Hammid *et al.* (1982), Khan and Davis (1982), Dolberg *et al.* (1981), Davis *et al.* (1983), Saadullah (1986), Tareque and Saadullah (1988), Hossain (1991) and Saadullah *et al.* (1989, 1990 and 1991). The effect of dietary fishmeal in improving milk production, growth rate and general health of the animal was judged to be positive in 84% cases in on-farm trials (Saadullah *et al.*, 1988). It is concluded that superimposing a daily supplement of 75 g of fishmeal on normal village (Noakhali) feeding practices is an option from a technical point of view, which confirms the on-station findings (Saadullah, 1984). This effect was more visible in cows than in calves and but the ecomonics are not enough to make this recommendation attractive for the farmers.

Practical methods of straw treatment in Sri Lanka were worked out by the straw utilization project (Ibrahim and Schiere, 1986). Straw supplementation with 2% urea was done by Pathirana (1983). Economics for Sri Lankan farmers were worked out by Nell (1986) and showed that not only straw/concentrate price ratio was important but also the level of animal production, being favourable at medium levels of production. It is also important that farmers are able to sell their milk.

FARMERS OPINION ABOUT THE NEW TECHNOLOGIES

In general the benefits as expressed by farmers in Bangladesh were that when they fed urea (ammonia) treated straw (Tables 11 and 12) they did not need to buy oil cake. Moreover there was an increase in the persistency of lactation and some farmers were able to make a profit by buying lean cows and selling them in a good condition later. Still, not many farmers continue straw treatment for reasons as listed below.

Table 11 Self-sufficiency of straw for animal feeding according to the different categories of farms at Lebukhali, Potuakhali, Sri Lanka

Farm category	Percent farmers responded not sufficient for animal feed	Reasons
Landless	77	c,f
Marginal	36	a,b,d,e
Small	45	a,b,c
Medium	30	a
Large	25	a

Source: FSR, Patuakhaliki, BARI (1988).
Notes: a = straw is not sufficient; b = land is not available; c = no purchasing capacity; d = straw used as fuel; e = straw made to make house; f = no land to grow fodder or pulse

Table 12 Farmer opinion regarding the feeding of urea treated straw in the village Kazir shimla, Mymensingh, Bangladesh.

Opinion	Farmers response in percent		
	Yes	No	No response
1. interested in feeding improved feed	100	-	-
2. willing to spend extra money for improved feed	83	16	-
3. straw intake is higher with cattle are fed urea treated straw	67	-	32
4. cattle fed urea treated straw improves health and productivity	66	-	33
5. willing to treat the straw without project help	16	33	50

Source: Farming Systems Res. & Dev. Program, BAU, Mymensingh (1986-1987) : 11

The farmers' opinions as grouped into livestock feeding systems on the basis of farm size (landholding) are shown in Table 10. Landless and marginal farmers (77% and 36%) reported that they do not have enough straw to feed their animals round the year.

These farmers constitute more than 50% of the total households. Other categories of farmers also indicated a shortage of straw for their animals round the year. The limitation of this shortage of straw interfered with the promotion of straw treatment although farmers indicated that they were getting benefits out of this technology (see Table 12).

In Sri Lanka, a few hundred farmers took to straw treatment in 1985/1986, but adandoned the method later because either there was abundant green forage, a problem of storage, or low animal productivity. In fact, much of the extension work was done where straw treatment was not appropriate in the first place, due to the reasons mentioned above.

During the rice harvest farmers have little time to spare for collection and storage of straw nor are they inclined to give thought to cattle feeding problems of the future. Their energies at that time are directed first towards harvesting and marketing of the rice followed by land preparation for cultivation in the next cropping season.

The farmers in both countries that still continue straw treatment, do so only when they have plenty of straw, no access to grass, and when milk production and sale warrants expenses on feed such as straw treatment.
Both in Bangladesh and Sri Lanka much of the straw is lost during the monsoon when harvesting coincides with (irregular) rains. It would be good if appropriate methods could be developed such as application of ammonia or slaked lime as a preservative for wet straw (Saadullah *et al.*, 1981).

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UREA-AMMONIA TREATMENT OF STRAW UNDER VILLAGE CONDITIONS REASONS FOR SUCCESS AND FAILURE

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SUMMARY

Adoption of urea-ammonia treatment technology under village conditions depends on the effectivenes of urea treated straw in terms of animal responses, economics of feeding urea treated straw as compared to untreated straw or other feeds, and practical constraints faced by the farmers. Improvement of feed quality after treatment depends on the level of urea and moisture, initial quality and type of straw, duration of treatment, temperature in the stack and systems used for the treatment under a given environment. The overall economics of feeding treated straw depends on the animal response, saving of concentrate and oil cakes and availability of green fodder. High cost of urea, labour, water, straw, lack of awareness, or low price of product (milk) and other socio-economical conditions of farmers are constraints which lead to failure of technology in farming systems that are in no real need of this technology.

INTRODUCTION

Urea-ammonia treatment of straw is a technically effective and feasible on-farm technology to improve the nutritive value of fibrous crop residues. The feeding of urea-treated straw alone can give extra 0.10 - 0.15 kg LWG in growing and 1 - 1.5 kg milk in lactating animal per day per animal (Khan and Davis, 1981; Perdock *et al.*, 1982). However, the method seems to be useful only for certain farming systems and many farmers who once adopted the technology have given it up whereas only a few are continuing to treat straw (Rao *et al.*, 1993; Saadullah and Siriwardene, 1993; ISPA, 1991). This presentation lists probable reasons for success and failure of adoption of urea treatment technology by the farmers, considering that under practical farming conditions the adoption of urea treatment mainly depends on the following factors:

- effectiveness of urea treated straw to give animal responses;
- economics of the technology;
- practical constraints faced by the farmers.

Specific extension issues are discussed by Rao *et al.* (1993), economics are discussed by Kumar *et al.* (1993) and this paper discusses the technical reasons for success and failure.

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EFFECTIVENESS OF UREA TREATED STRAW TO GIVE ANIMAL RESPONSES

Animal response depends on the possibility of urea treatment technology to yield a uniform quality of straw and the proportion of straw incorporation in the diet. Other factors relate to the animal itself to give adequate responses, such as productive state and health of the animal. Details of such factors are discussed in other papers (Ibrahim, 1986; Schiere and Ibrahim, 1989; Walli *et al.*, 1988; Sewalt and Schiere, 1989).

ECONOMICS OF ADOPTION OF STRAW TREATMENT

Economics may be calculated in different ways and are discussed with field experiences by Kumar *et al.* (1993). Farmers can visualize benefits in the form of:
- saving of concentrate or green fodder (and land required for production of green fodder);
- extra milk produced;
- daily cost to be spent on feeding the animal.

The economics are influenced by factors such as enumerated by Nell *et al.* (1986), Singh (1987), Vijayalakshmi *et al.* (1988), Singh *et al.* (1988), Rai and Agarwal (1991) and Schiere and Nell (1993). Successful adoption of urea treatment technology is likely in situations of:
- availability of good straw, labour, water, urea;
- reduced availability of green fodder and concentrate or local quality supplements.

Good availability in economic terms implies low prices, and so does non-availability result in high prices, though official prices may not always reflect actual availability.

On farm trials with feeding of urea treated straw to lactating animals around Bangalore (Karnataka), Karnal (Haryana), Baroda (Gujarat) and Kalyani (West Bengal) indicated extra yields of 0.5 - 1.5 kg milk and/or saving of 20-30% concentrate with a reduction of feed wastage of 20-30%. Rai and Mudgal (1988) reported an economic milk production on urea treated wheat straw by buffaloes. Buffaloes producing 5 kg milk/day with 7.8% fat could be maintained on urea treated wheat straw with 2 kg concentrate/animal/day. Urea treated straw has a nutritive value which approaches that of non-leguminous fodders, but with a higher level of soluble nitrogen. Animals that are underfed (Perdock *et al.*, 1982) give good response to urea treated straw feeding. Feeding of urea treated straw mixed with green legume fodder like berseem gives better response (Singh, 1983). In growing animals DMI may be improved by 20-30% giving extra gain (g/d) of about 100-150 g for animals around 100-150 kg LW. An increase in growth rate from up to 140 g/day in growing animals fed on urea treated straw was obtained under field conditions of the Pantnagar area (Agarwal *et al.*, 1987). Increases of animal production due to introduction of straw treatment at farm level is difficult to measure, because the introduction is generally confounded with aspects such as reduced concentrate levels, same amounts of straw on offer with decreased feed wastage, or even better attention of the farmer for animals "in the experiment". One of the problems is in assessing the economics as the farmer sees them. The benefit of feeding of urea treated straw goes in favour of farmers more interested in sale of milk, i.e. those who take dairy as a business, whether large or small.

Around G.B. Pant University (Pantnagar, Uttar Pradesh) urea treatment of straws was introduced between 1980 to 1984 in three phases involving animals of 22, 28 and 15 families. These farmers fed treated straw ranging from a mere 400 to 90000 kg per farmer depending on the availability of animals and straws in different seasons of the year. Under farm conditions where animals were carefully fed to produce milk for sale, the introduction of urea treated straw feeding (as compared with untreated straw) can:

- save concentrate;
- reduce land area required for green fodder production;
- increase milk yield with 1-2 litres/animal/day.

Since the introduction many farmers have given up the treatment of straw due to limitations, the majors ones being:

- the effects were not positive but slow and not as large as expected;
- labour problems at harvest, and the system proposed included treatment at time of harvest, rather than in small batches as in Karnataka or Sri Lanka;
- cost of urea hinders its use for treatment of straw.

At present three farmers of the Pantnagar area are still regularly treating their wheat and paddy straws depending upon their need. All three are (large land lords) actively engaged in milk production and who dispose of the milk directly into the city of Haldwani.

In other places of India straw treatment was also popularized, such as in:

- <u>Karnal</u>
  Here the problem for treated straw introduction is that except for a few months in the year, there is an abundant supply of green fodder during the winter. The treatment was done in relatively large stacks and for a few weeks duration or longer, as in Pantnagar. Wheat straw is included as a filler for the legume based rations and use of rice straw is avoided, partly due to fear of Degnala disease. The treatment method was introduced by using 4 kg urea with 50 liters of water for 100 kg air dried paddy straw, urea solution was sprayed layer after layer and covered with polytheine sheet. Whenever polytein was not available, the treated material was covered with bags. Lack of proper sealing led to complaints about mould development (Walli *et al.*, 1988). The use of large batches for treatment follows the traditional practice of straw storage, as explained by Rai *et al.* (1993).

- Gujarat

  In various agro climatic conditions of Gujarat, BAIF has undertaken on farm trials with urea treatment of straw (wheat, paddy and local forest grasses), at under farmers conditions. The trials were conducted in Baroda, Surat, Bharuch, Valsad and Ahmedabad, Panchmahals and Bhavnagar district with more than 200 farmers. After 2 years only 15 - 20 farmers continued the practice of urea treatment of straw. Reasons for non adoption include:
  - feed rejection by animals in initial stage and hence more wastage of straw;
  - many farmers have low yielding animals and no large absolute increase in milk (from 0.5 l to 1.5 l per day) was observed;
  - it was difficult to store grass for a long period due to poor availability of grass;
  - wheat and paddy straw, as well as local grasses are available;
  - in remote areas grasses are not available and farmers have to manage with available crop residue;
  - farmers considered treatment labourious;
  - material such as urea, plastic cover or even grass is less available;
  - water for treatment is also great problem in same areas;
  - economics of the technology were disappointing;
  - farmers having plenty of green fodder do not require straw treatment.

Reasons for success in Gujarat:

only farmers with good yielding animals have accepted the technology, when they had:
- an ample availability of material;
- farmers that produce cash crops like cotton, tobacco or horticulture felt it advantageous as wastage of straw at time of feeding is reduced and more land can be devoted for cash crops;
- poor quality grass can be utilised;
- an increase in milk production;
- in dry areas green fodder can be scarce;
- in cash crop area with a poor availability of grazing land;
- improvement in hair coat; i.e. a more healthy appearance of the animal.

- Bangalore

  The approach followed here was to treat straw in small batches as required for feeding in the next week, with a short duration of approximately 1 week, rather than in one stack as in Pantnagar and Karnal. The long term storage was done in dry untreated form, following tradition in that region. Commercial urban farmers found it problematic to treat the straw because it exhausted their stacks of purchased straw sooner. Village farmers were reluctant to accept when they could not sell the milk. Some farmers who sell milk and have sufficient access to straw still continue the practice. Experiences as registered here correspond very well with those of ISPA (1991), Saadullah and Siriwardene (1993) as well as Schiere and Ibrahim (1989).

PRACTICAL CONSTRAINTS FOR STRAW TREATMENT AT FARMERS LEVEL

The treatment technology shows positive animal responses and is relatively simple. Therefore, feeding of urea treated straw could be useful to dairy farmers under certain conditions and some of the farmers are indeed making good use of it. However, many of the farmers report additional constraints for the application, such as:

- farmers traditionally tend to feed the working bullocks and lactating animals on better feeds (green fodders and concentrate) to get more draft power and milk. Mass media talks also explain how farmers should grow green fodder throughout the year to get better production, and farmers know that feeding of green fodder produces more milk than feeding of straw. Straw feeding therefore seems illogical to them. Secondly, green fodders are available on sale even in cities and straw in cities is very expensive. Farmers who sell some milk for cash to meet their daily expenses, tend to go for green fodder production/purchase for feeding of lactating animals when green feed is available. Farmers who do not sell milk are also unlikely to buy green fodder and concentrates and do not spend money on straw treatment.
- non-availability of inputs and other facilities:
  - insufficient cash to spend on urea and other inputs for treating the straw. Rural poor always need money to feed the family members, they always has to make decisions whether to go for earning the cost in the day or to spend money and effort with treatment of straw to obtain future benefit.
  - straw is often not abundantly available.
  - in some areas during the dry season a scarcity of water exists even for drinking water.
  - to treat straw in larger quantities, sufficient amounts of straw, urea and labour are required, which may not be available at once. This can be overcome by treating straw in small batches of about a week as done in Bangalore and Sri Lanka (Schiere and Ibrahim, 1989).
  - the harvest is often advised to be the most convenient time for treating the straw, especially when straw is treated in large batches by large farmers. In that way it follows the traditional pattern of storage. But the labourers are generally busy at that time, taking care of the grain harvest, i.e. insufficient labour is available. Especially small farmers can solve this problem by treating in small batches.
  - the availability of crop residues is seasonal and regional. If straw is to be purchased it is likely to be to relatively expensive when not used for commercial dairying.

- the rate of straw consumption increases by about 30% or more. Where straw is not plentiful (and where prices are higher) farmers feel they exhaust their straw stock too soon.
- positive economics from feeding of urea treated straw can only be expected if straw constitutes about 50% or more of the diet. However, high proportions of treated straw cannot provide an adequate nutrient supply for milk production levels much higher than the equivalent of one time maintenance (i.e. roughly 8 lts. for a 350 kg cow and more for heavier cows). Beyond such levels the adequate utilization of nutrients and maintenance of milk production requires increasing amounts of either concentrate or green fodder (Rai and Mudgal, 1988). Farmers generally do not see the economics of feeding of urea treated straw when the response is difficult to measure and often not clearly defined by the extension service (Rao *et al.*, 1993).
- some animals have problem of loose faeces which is a difficulty for families that use dung to prepare dungcakes for when the faeces is sticky, the animals are also difficult to clean.
- the animal may initially refuse to eat the treated straw due to the smell or other reasons.
- many farmers have animals of different age, size and not all are in production. Farmers feel they would waste money on unproductive animals by feeding treated straw to them.
- farmers prefer to feed small amounts of green fodder or kitchen waste as supplement (Saha and Singh, 1993). These small supplements may serve the animal better than treatment of straw, especially when the animals are low producers.
- many farmers fear that the health or reproductive capacity of their animals maybe negatively affected after introduction of feeding straw, though literature shows that the opposite is more likely to be true (Sewalt and Schiere, 1989).
- for large farmers the labour availability at the time of harvest may be a constraint to collect and/or treat all the straw. Smaller farmers may have problems with availability of straw, urea or marketing of milk.

REASONS FOR ADOPTION

Though not many farmers are using the treatment technology, some are in fact continuing after adoption. Reasons for adoption may differ between farming systems and should be clearly specified before taking to extension (Rao *et al.*, 1993). Some of the reasons for continued adoption include:

- saving on concentrate, occur (only) when (treated) straw is cheap compared with concentrate, and at levels where (treated) straw can be a substantial part of the ration (Rai *et al.*, 1988),
- increased milk production and butterfat content,

- reduced wastage,
- savings of land that otherwise would be needed for fodder production.

Summarizing it can be said that straw treatment is useful mainly where:
- straw is cheap (plenty available) when compared with concentrate, green feeds and other supplements,
- animal production levels allow inclusion of straw as a major part of the total ration,
- the produce of the animal can be sold at good price,
- inputs such as water, urea, covering material are easily available.

CONCLUSIONS

Urea treatment of straws is simple, and can be attractive economically to farmers engaging in commercial production and sale of milk, provided there is a good supply of cheap straw/dry grass for treatment, urea and other requirements. Labour availability can be constraint especially for large farmers. The majority of the farmers feel that they don't need the technology for several reasons other than the variable animal responses. Adoption of the technology has been poor because often it was introduced into farming systems or seasons that were actually not in need of technology. Introduction and on farm testing is useful only in farming systems that are likely to benefit as described in this article.

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AN ECONOMIC EVALUATION OF UREA TREATMENT TECHNOLOGY OF STRAW ON FARMS - A REVIEW

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SUMMARY

Any technology needs critical evaluation and preceding economic analysis before it is recommended for field application on a wider scale. In addition to results obtained at research stations, comparison of results with 'On-Farm Animal Trials' would serve as a basis for adoption of any technology. Development of urea treatment of cereal straws has the potential to overcome the shortage of feed in certain farming systems. The treatment technology is simple and reproducible. Results of 'On-Farm Animal Trials' under different agroclimatic and socio-economic situations in the country are reviewed together with the economics of urea treatment of straw.

INTRODUCTION

Nutritional surveys in various parts of the country show that animals are mostly maintained on straw-based ration (Maruthiram *et al.*, 1976; Mudgal and Sampath, 1972; Patel, 1970). Animals on such rations often suffer from poor nutrition (Amrith Kumar *et al.*, 1980), depending on the production goal for which they are kept. Therefore, the improvement of the nutritional values of straw holds promise, for the future. Urea treatment of cereal straws is presently used to a small extent at farms where straw is being fed to cattle (Aggarwal and Rai, 1986; Toro and Maggonkar, 1986) and is tested in several other areas of the country. The results of these trials along with their economics are discussed below, under the following headings :

- on-station research (OSR);
- effect of feeding (treated) straw on growth and milk yield;
- on-farm animal trials (OFAT);
- economics of feeding urea treated straw.

ON-STATION RESEARCH

On-station research is a pre-requisite to OFAT. Urea treatment improves the nutritive value of (rice) straw (Amrith Kumar *et al.*, 1993) and feeding of treated straw (TS) can maintain cattle and buffaloes without addition of supplements (Wanapat, 1985; Wongsrikeao and Wanapat, 1985). Supplements are needed to support

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higher levels of growth and milk production when straw forms the major portion of the ration. There exists considerable variation in the method of treatment of straw with respect to level of urea, water and also the duration of treatment period (Rai *et al.*, 1993). The composition of concentrate mixture, or type of greens used also influences the final result.

FEEDING (TREATED) STRAW IN ON-STATION RESEARCH

Creek *et al.* (1984) reported higher LWG in steers fed TS than on US. To obtain a similar magnitude of gain with US, higher level of concentrate was needed. Similar observations were recorded in growing animals fed TS/US and supplements (Saadullah, 1984; Promma *et al.*, 1985; Schiere *et al.*, 1988; Rai and Mudgal, 1990). These studies indicate that the use of TS in the ration supports higher animal production at lower (concentrate) supplementation rates, depending on the level of production. The savings on supplement are caused by increased higher quality of TS, mainly because the DMI of TS is higher than on US. This means that concentrate is replaced by straw in the case of TS.

Cows sustained on US and concentrate mixture throughout their lactation recorded a lower total milk yield than those fed greens (10 kg), US and concentrate (Amrith Kumar, 1978). Cows on TS maintained a higher yield at reduced concentrate levels (30%) compared with those fed US and concentrate (Bhaskar *et al.*, 1992). Dahiya *et al.* (1990) fed buffaloes TS along with greens (10 kg) and concentrates and recorded a reduction in concentrate mixture by 25%. The concentrate savings depend largely on the quality improvement of the straw and on the level of production of the animal.

It is clear from the OSR, that use of *ad libitum* TS in the ration allows a reduction in supplementation without affecting either growth or milk yield, as compared with the use of untreated straw (US). This is consistant with those reported earlier (Ibbotson *et al.*, 1984; Barker *et al.*, 1987; Yackout *et al.*, 1985).

ON-FARM ANIMAL TRIALS

On-Farm Animal Trials (OFAT) are complimentary to OSR. In this approach, the technology is evaluated on the animal in the farm environment, with farmers participation. Factors that affect the rate and level of adoption (Rao *et al.*, 1993; Singh *et al.*, 1993) and include:
i) additional revenue obtained from the adoption,
ii) reduced cost of feeding as a result of change,
iii) revenue foregone as a consequence of the change,
iv) extra cost incurred due to implementation of technology.

The change should be adopted if i + ii > iii + iv. In that case the technology can be considered for wider application. Implementation of any technology or changed management requires:

- identification of resource potential, motivation of the farmer and existing feeding practices;
- justification of the intervention;
- modification of technology according to farm conditions;
- *ex ante* determination of economic advantage (Amir, 1986; Potts, 1982).

The active participation of farmer in OFAT has the following advantages:
- the farmer learns a new technology/ management;
- it helps to adjust the technique to farming conditions.

There are also problems associated with farmers involvement (Farrington and Martin, 1988). Such problems include the choice of farmer, the farmers influence on management of the trial etc. About on-farm livestock trials some specific issues are discussed by Gryseels (1988). They are based on problems of numbers and indivisibility of animals, problems of long-term effects and emotional value attached to livestock as compared to crops etc. The success of transfer of technology (TOT) depends on the involvement of researcher, the usefulness of the innovation and the interaction with the farmer. On-farm studies with urea treatment of straw in different "Farming systems" are reviewed below by Singh *et al.* (1993) and Saadullah and Siriwardene (1993).

ECONOMICS OF FEEDING UREA TREATED STRAW

The cost of feeding is a major part of total costs of milk production (Singh *et al.*, 1993; Achten and Tollens, 1987) and hence reduction of feeding cost of dairy cows is a major concern. Where the cost of concentrate is high compared with straw, and when adequate greens are not available, the cost of maintenance will be high. The cost of maintenance on US and TS rations is given for some cases in Table 1.

Table 1 Cost of maintenance with US and TS based ration for some case studies

Places	Combination of feeds/fodder	Quantity (kg/day)	Cost (INR/day)	Reference
Bangalore (Karnataka)	US + Groundnut Cake	5.15 + 0.49	5.39	1)
	TS	5.19	4.15	
Madurai (Tamil Nadu)	US + RiceBran + Groundnut Cake	3.00 + 1.33 + 0.323	3.09	1)
	TS + RB	3.00 + 1.40	2.50	1)
Ranipet (Tamil Nadu)	US + Greens*	2.33 + 30	6.30	2)
	US + Greens* + Conc.	8.0 + 5.0 + 2.0	10.80	2)
	TS* + Greens*	8.0 + 5.0	7.50	2)
Sri Lanka	US + Rice Bran	7.0 + 0.8	0.83	3)
	TS	6.3	2.62	

* fresh matter; 1) Vijayalakshmi et al. (1988); 2) Viswanathan (1990, pers. comm.); 3) Schiere et al. (1988)

The cost incurred on maintenance cannot be recovered through saleable product, but it is an investment for future produce. Technology that reduces the cost of maintenance, is quite welcome. Use of greens in place of concentrates is economical when greens are cheaper on a nutrient basis than concentrate (Bajpai *et al.*, 1983). When greens are scarce or expensive, the use of TS as an alternative holds promise, provided that nutrients from straw are cheaper than from greens, and treatment is not too costly. Not much work has been done on this aspect, but some reports indicate that using TS in feeding animals reduced the cost of maintenance (Table 1). An opposite trend is reported (Schiere *et al.*, 1988) for Sri Lankan rural systems, where maintenance was cheaper on untreated straw + supplement than on TS alone. A commercial farm in Tamil Nadu is using TS extensively, reduced the cost of maintenance feeding by about INR 4000 per month (Table 1), for the whole herd.

METHODS OF UREA TREATMENT OF STRAWS

An attempt has been made to document the methods of urea treatment in the country, to elucidate the causes for non-uniform results. Rice straw is used for ruminant feeding in many parts of the country, though not much in the Haryana/Punjab. Wheat straw is fed mostly to the Northern belt. One of the striking features in the North with regard to (rice) straw is that it is chaffed and fed and the same practice is carried over for urea treated straw also. In the South, chaffing of fingermillet or rice straw is not commonly practiced. Chaffing adds on to the cost and a further explanation of these different practices is attempted by De Wit *et al.* (1993). Other differences in methods of straw treatment include the level of moisture used in studies in Northern India which varies between 30-50% (Rai *et al.*, 1993). Despite differences, the results obtained were consistent with reduced concentrate requirement (25 - 30%) for milch cows, depending on the production level (Dahiya *et al.*, 1990; Bhaskar *et al.*, 1992).

From the foregoing the following points can be made:
- chaffing is not a pre-requisite for urea treatment;
- urea treatment of straw obviates chaffing, if chaffing is practiced to reduce manger losses;
- using either chaffed or long urea treated straw produces similar results;
- standardization of urea treatment method is difficult, considering the different types of straw to be treated, and the differences in local farm conditions (Schiere and Sewalt, 1988).

COST OF FEEDING (TS VERSUS US) DURING LACTATION IN RURAL AND URBAN AREAS

Vijayalakshmi *et al.*(1988) used ration formulation with linear programming to compare the cost of milk yield for an entire lactation period on US and TS based rations. The milk yield at early, mid and late-lactation in cows both at rural and urban Bangalore has clearly shown that TS-based feeding can be economical (Table 2). The price ratio of straw/concentrate, together with the required feed ratio straw/concentrate for different levels of production, affects the economics of TS versus US feeding at different production levels (Schiere *et al.*, 1988).

Bhaskar *et al.* (1992) showed that milk production profiles for a TS group were consistantly higher than for the group fed on US, indicating that feeding TS to cows over their entire period of lactation adds to the profit in terms of reduction in feed cost with sustained higher milk yield for the conditions of their study. An increase of 1 kg milk at peak milk yield, gives an increase of 200 kg over the entire lactation as reported for Canadian conditions by Murray (1985). Such a benefit is likely to accrue if TS is used immediately after calving. The price ratios between (treated) straw and concentrate will determine the economics, depending on the level of production as explained below after parturition. This aspect needs to be evaluated.

Table 2 Comparision of calculated cost of feed at different stages of lactation in rural and urban areas of Bangalore (INR/animal/day)

Stage of lactation	Average levels of milk production (kg)	Rural		Urban	
		TS	US	TS	US
Early (12 weeks)	10	949	1218	1,189	1,275
Mid (12 weeks)	7.5	449	605	583	648
Late (20 weeks)	5.0	350	543	490	651
Dry period (8 weeks)		136	204	232	302

Source: Vijayalakshmi et al. (1988)
Notes: TS: Urea treated straw; US: Untreated straw

COMPARING THE COST OF US AND TS BASED RATION AT DIFFERENT LEVELS OF MILK PRODUCTION

Cost of US and TS based rations at different milk production levels is presented in Table 3. The level of milk production ranges between 5-12.5 kg per animal per day. Inclusion of TS reduced the cost at some, but not at all levels of milk production, depending on the prices prevalent per farming system. In cases where cheap greenfeed (legumes) are introduced (Agrawal *et al.*, 1989; Singh *et al.*, 1988) the benefit of including TS could not be perceived. Rural farmers in Haryana could also not perceive the benefits of TS feeding, as TS was fed with berseem

Table 3 Cost of feed for different milk yield in cows fed US or TS based rations (INR/animal/day)

Place	Type of farming	Level of milk yield (liters/day)	US ration (INR/day)	TS ration (INR/day)	Source
Bangalore	Rural	5	7.75	5.00	Vijayalakshmi et al. (1988)
Bangalore	Urban	5	9.30	7.00	- ibid -
Madurai		5	5.29	4.25	- ibid -
Chittoor		5	8.51	6.20	- ibid -
Pondicherry		5	5.10	3.56	- ibid -
Karnal		5	4.41	5.51	Rai et al. (1988)
Karnal	SF	5-6	8.34	8.40	Singh et al. (1988)
	LF		10.38	9.38	- ibid -
Sri Lanka	DZ	4	4.52 SLR	3.73 SLR	Nell (1986)
Sri Lanka	MC		6.29 SLR	5.53 SLR	- ibid -
Sri Lanka	HC		10.45 SLR	10.73 SLR	- ibid -
Sri Lanka		4	2.75 SLR	3.68 SLR	Schiere et al. (1988)
Bangalore	Rural	7.5	9.60	7.13	Vijayalakshmi et al. (1988)
Bangalore	Urban	7.5	10.28	9.25	- ibid -
Madurai		7.5	7.29	5.75	- ibid -
Chittoor		7.5	9.62	7.77	- ibid -
Pondicherry		7.5	7.25	4.41	- ibid -
Haryana		7-8	10.76	10.72	Dahiya et al. (1990)
Sri Lanka	DZ	8	8.86 SLR	5.81 SLR	Nell (1986)
Sri Lanka	MC	8	10.63 SLR	8.17 SLR	- ibid -
Sri Lanka	HC	8	14.97 SLR	14.95 SLR	- ibid -
Sri Lanka		8	12.37 SLR	5.05 SLR	Schiere et al. (1988)
Bangalore	Rural	10	14.50	11.30	Vijayalakshmi et al.
Bangalore	Urban	10	15.18	14.16	- ibid -
Madurai		10	9.60	8.45	- ibid -
Chittoor		10	11.36	10.38	- ibid -
Pondicherry		10	10.94	9.53	- ibid -
Karnal		10	7.59	6.97	Rai et al. (1988)
Pantnagar		11	10.79	10.86	Agrawal et al. (1989)
Sri Lanka	DZ	12	14.18 SLR	12.80 SLR	Nell (1986)
	MC		15.64 SLR	14.71 SLR	- ibid -
	HC		19.86 SLR	20.16 SLR	- ibid -
Bangalore		12.5	18.13	13.63	Vijayalakshmi et al.(1988)

Notes: (1) all costs in INR per day, but the Sri Lankan data are in Sri Lankan rupees (SLR) at roughly 1 INR = 2 SLR ; SF (small farmer); LF (large farmer); DZ, MC and HC refer to different farming systems in Sri Lanka.

and concentrate mixtures containing high level of groundnut cake (25-30%). In contrast, in conditions of South India, benefits in terms of cost were recorded in TS-based ration when greens were around 5 kg (fresh) and the concentrate mixture contained less cake (15%) (Sampath, 1989). When the daily milk yield is at 12.5 to 15 kg/animal, or where straw is expensive compared with concentrate supplements, the monetary benefit due to TS feeding was not much (Vijayalakshmi *et al.*, 1988; Schiere *et al.*, 1988).

A comparison was made between two farming systems, with data from Meerut (UP), and Bangalore (Karnataka). The resource availability of these farms is compared in Table 4. Concentrate feeding was similar between their cases, but the resources were different. In farms of Bangalore, the availability of greens was limited to around 5-10 kg/animal/day (fresh), while in Meerut, greens were better available. The economic benefits of TS feeding between these farms are summarized in Table 5. As a rule of thumb, many farmers are recommended to feed concentrates of 1.5 kg per animal for maintenance and 1 kg of concentrate for every 2.5 kg milk produced. This would work out to 400 g concentrate/kg of milk. In Meerut (UP), in all farms the concentrate/kg milk and maintenance ranged from 0.25 to 2.80 kg, while in Bangalore its levels were between 0.38 and 1.30 kg. As per convention, the requirement of concentrate would be 1.9 kg for maintenance and 1 kg milk. Feeding in most of the farms except one each in Meerut and Bangalore, the economy on concentrate was caused by TS feeding. The wide variation observed between farms is the reflection of differences in farm constraints.

Table 4 Resource Potential of Farms at Meerut District (U.P) and Bangalore

Farms	Status	Herd strength	Concentrate ingredients	Greens	Straws	Priority problem
MEERUT						
1	Agric.	150	Cake	Berseem	WS	--
2	City dairy	23	Wheat bran	Sorghum	WS	--
3	Agric.	33	Chunni	Maize	WS	--
4	Agric.	12	Chunni	Maize		--
5	Agric.	6	Chunni	Maize		--
6	Agric.	5	Chunni	Maize		--
BANGALORE						
1	Commercial	13*	Groundnut cake Wheat bran Gram husk	Hybrid Napier	RS	Infertility, highcostoffeeding
2	Commercial	22*	Gram husk	Hybrid Napier	FMS	"
3	Commercial	11*	Gram husk	Horticultural residues	FMS	"
4	Commercial	50	Groundnut cake Wheat bran Gram husk Maize grit	Hybrid Napier	FMS	Abortions, infertility high of feeding
5	Commercial	100	Home made Conc. mixture	Hybrid Napier Napier	RS	

WS = wheat straw; RS = rice straw; FMS = fingermillet straw; * only cows in milk.

Table 5 Comparison of economic benefit of feeding urea treated straw at Meerut (UP) and a rural farm in Bangalore.

Farms	Number of cows in milk	Annual milk yield (kg)	Annual yield per cow (kg)	Livestock Unit (LU)	Annual benefit from TS/LU (INR)
Meerut (1 year data)					
1	60	111376	102200	150	715[*]
2	23 (buffalo)	54750	36500	23	249[*]
3	7	12775	36500	33	33
4	4	7300	2920	12	22
5	2	4380	1100	6	33
Ranipet (6 months data)					
1	13	10800	830	-	-
2	22	43200	1963	-	-
3	11	19440	1767	-	-
4	50	86400	1728	-	-

[1] Mahendra Singh et al. (1988); [2] Amrith Kumar et al. (1990);
[*] used 3301 quintals of wheat bhusa per year; [*] used 730 quintals of wheat bhusa per year

CONCLUSIONS

The following conclusions are drawn on the economics of urea treatment of straw in the country:

- urea treatment improves nutritive value and intake of straw;
- effected the reduction (25 - 30%) of concentrate without affecting milk yield;
- urea treatment is not beneficial where legumes or other feeds are readily available and
- urea treatment can overcome the shortage of quality feeds to some extent, provided that there is enough straw.

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PRACTICAL METHODS AND OTHER ISSUES OF UREA-AMMONIA TREATMENT OF STRAWS - A REVIEW

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SUMMARY

Urea treatment is a proven technology to upgrade the nutritive value of straw, but the practical application and economic feasibility differs between farming systems. A large variety of treatment methods has been used in different parts of the country and the choice between them is determined by the situations prevailing in a particular farming system. The variable response to urea treatment of straw may be reckoned to be caused by differences in initial straw quality and efficiency of the process. The level of urea required, amount of water used, duration of storage period, type of storage structures and volume of straw used is reasonably well established, as reviewed in this paper. Owing to large variability in (Indian) farming conditions, a uniform recommendation is unwise and impossible.

INTRODUCTION

Cereal straws have a low nutritive value (Singh and Oosting, 1993). It is needless to emphasize the importance of cereal straws in ruminant diets especially in South-east and South-Asian countries as they constitute by far the largest proportion of roughage in the rations. Many animals survive on such roughages alone. A variety of treatments has been reviewed by Sharma *et al.* (1993) but their cost effectiveness and suitability in different farming systems are variable (Kumar *et al.*, 1993; Singh *et al.*, 1993). The main objective of treatment of straws is to improve its feeding value. This paper reviews practical aspects of methods for urea-ammonia treatment of straws with regard to factors affecting the efficiency of ammoniation process, and considering aspects that cause difference in practical methods to be followed in particular farming systems.

Concentration of urea

In practice, 4 kg urea dissolved in 60 - 100 l of water per 100 kg straw is used. This level of urea has been found to be optimum in India and Sri Lanka (ICAR, 1985; Jayasuriya and Perera, 1982; Verma, 1983; Puri, 1988; Rai and Mudgal, 1989; Gupta *et al.*,

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1990; Rai *et al.*, 1990; Subba Rao *et al.*, 1993). This recommendation of 4% urea is based on the work of Sundstøl *et al.* (1978) who showed substantial improvement in the in vitro digestibility by increasing the ammonia levels from 1.0 - 2.5% and smaller improvement when increasing ammonia up to 4.0%. The optimum level lies probably between 2.5 and 3.5 kg NH_3 per 100 kg straw dry matter. One kg of urea on hydrolysis yields approximately 0.57 kg ammonia (NH_3) and the urea equivalent of 2.5% NH_3 is about 4.4%. Rai and Mudgal (1988) applied NH_3 ranging from 2 - 20% of DM and noticed that 2% NH_3 level was found most effective in increasing DM digestibility. This level of ammonia is equivalent to 3.5% urea. They further noticed that use of NH_3 beyond 2% increases the loss of ammonia from treated straw progressively. The effect of urea concentration on dry matter digestibility is shown in Table 1. Variations in optimum levels of urea and NH_3 can be partly explained by the way the nutritive value is assessed. Most work is done with *in vitro* measurements of digestibility which can show a different optimum than *in vivo* or DMI measurements. When DMI is taken as a measure of nutritive quality the optimum is reached at lower urea levels than when only OMD is measured, as shown in Table 1 (Ibrahim, 1986).

Table 1 Effect of urea concentration on *in vivo* DMD (%) of straws

Type of animal	Urea Concentration (%)						Source
	0	3	4		5	6	
RICE STRAW							
Cow	40.0	-	-	-	51.0	-	Saadullah et al., 1981
Cow	49.0	-	-	-	63.0	-	Hossain and Rehman, 1981
Cow	41.0	-	-	48.0	-	-	Ibrahim, 1985
Cow	44.0	-	-	-	51.6	-	Wanapat et al., 1984
Cow	43.0	-	-	48.0	47.0	-	Ibrahim and Schiere, 1985
Buffalo	43.2	-	52.7	-	55.4	-	Wongsrikeao and Wanapat, 1985
Buffalo	50.2	-	-	-	51.9	-	Wanapat et al., 1984
Bullocks	46.5	-	-	52.1	-	-	Subba Rao et al., 1993
Bullocks	46.9	-	-	54.4	-	-	Kumar et al., 1993
Bullocks	52.0*	48.0*	-	57.0*	-	55.0*	Ibrahim, 1986
Bullocks	48.0	-	-	55.0	-	53.0*	Navaratne, quoted by Ibrahim, 1986
FINGERMILLET							
Bullocks	49.3	-	-	59.9	-	-	Rao et al., 1993
WHEAT STRAW							
Cow	52.6	-	-	59.8	-	-	Rai and Mudgal, 1989
Buffalo	49.4	-	-	59.7	-	-	Rai and Mudgal, 1989
Buffalo	56.5	-	-	60.9	-	-	Rai and Gupta, 1990
Buffalo	-	-	-	47.5	45.2	48.3	Walli et al., 1990

Note: * OMD

Requirement of water

Moisture content is another factor determining the effect of ammoniation process but the quantity of water is not very critical. The basic function of water is to dissolve and hydrolyse the urea. Water also acts as a vehicle to move ammonia compounds in the straw. Waiss *et al.* (1972) concluded that an optimal effect of the ammonia treatment was obtained at a moisture content of about 30%. Sundstøl *et al.* (1979) found that increasing the moisture content of the straw from 12 to 50% had a positive effect on digestibility of ammoniated straw. Upadhyay (1989) observed best results with 40% moisture level using from 20 to 40% moisture content with different levels of urea for the straw treatment. The water holding capacity of straw ranged from 0.8 to 1.0 kg per kg straw therefore, using water beyond 100 l per 100 kg dry straw is not justified. The waterholding capacity can increase only beyond 100 l/100 kg DM when straw is left to soak for some time, as is done for biological treatment, to allow fungal growth. This is not required for chemical treatment. In fact, when straw gets too wet, the mould growth may take place which spoils the urea ammonia treated straw, particularly if ammonia escapes. Moreover, in (semi)arid situations water is often scarce especially during summer, and water usage needs to be minimized. An amount of water ranging from 30 - 65 l per 100 kg straw seems to be optimum depending upon the water availability. The demonstrations conducted in the villages around Karnal using 50 l water per 100 kg air-dry straw was found suitable. The findings on effect of different moisture content on digestibility and intake have been presented in Table 2 and combinations of different moisture levels with urea levels is shown in Table 3.

Duration of treatment

It has been reported that liberation of NH_3 starts at the sixth hour and reaches about 1% to 1.1% by 24 hours (Kumar *et al.*, 1993). Possibly ammoniation periods of only 7 days or less are required under tropical conditions. Various reports indicate the duration of treatment ranging from 3 days to 3 weeks in warm climates and 8 to 13 weeks in cooler regions. There is no absolute maximum duration for treatment on technical grounds, except that a longer period of treatment may increase the occurrence of fungi, especially in rice straw where stack compactness is less than in wheat straw. The most suitable duration can be decided upon according to local circumstances. In many farming system straw (rice) is traditionally stored in large open stacks for many months. In such situations it may be advisable to treat the straw with urea at the time of stacking though this implies a greater labour requirement at harvest. If treatment is to be for a longer period, care should be taken to prevent the development of moulds, by sealing and compacting the stack well. Some *in vivo* data on duration of ammoniation of straw as compared to untreated straw on digestibility are presented in Table 4.

Table 2 Effect of water level, and period of treatment on DMI and digestibilities of straws

Substrates	Water level (l/100 kg straw)	Period of treatment (days)	DMI (kg/100 kg BW)	DMD (%)	Source
Rice straw	0	untreated	1.7	51	Ibrahim and Schiere, 1988
	0		-	46	Soejono, 1986
	0		1.7	47	Subba Rao et al., 1993a
	0		1.6	47	Kumar et al., 1993
	30		2.3	56	Ibrahim and Schiere, 1988
	60		2.2	58	Ibrahim and Schiere, 1988
	60		1.9	52	Subba Rao et al., 1993a
	100	21	2.1	62	Ibrahim and Schiere, 1988
	100	7		51	Soejono, 1986
	100	1	1.8	53	Kumar et al., 1993
	100	21	2.1	59	Kumar et al., 1993
Fingermillet straw	0		1.6	49	Rao et al., 1993b
	100	21	2.1	59	Rao et al., 1993b

Table 3 Effect of moisture and urea levels on NBDMD percentage of treated straw (Verma, 1983) *)

Moisture level % on the straw	Urea Levels (%)			Mean
	3	4	5	
45	51.8	53.5	53.4	52.9[a]
55	52.9	53.2	53.9	53.3[a]
65	50.5	51.5	52.0	51.3[b]
75	48.3	49.5	50.2	49.4[c]

*) means with different superscripts were significantly different

Table 4 Effect of duration of ammoniation on digestibility in cows (Soejono, 1986)

Particulars	Untreated	Duration (week)		
		1	2	3
IVDMD (%)	35.7	39.4	42.4	41.5
VIVO OMD (%)	45.5	51.4	53.5	52.9
DE (MCal/kg)	1.23	1.43	1.52	1.59

The duration required for treatment often depends on the practical situation of the farming system under consideration. A number of factors are involved such as:
- practicality of the system;
- compactability of the straw;
- ambient temperature and
- addition of urease.

- Practicality of the system
The treatment can be done in one large sized stack immediately after harvesting as done at Pantnagar and around Karnal.

Treatment can also be done weekly or fortnightly in small batches as is done in the Southern parts of India, West Bengal, and also in Sri Lanka. The choice depends on local practice, straw and labour availability. It is quite possible that large farmer prefers to treat all the straw in one batch right at the time of stacking after harvest, whereas small farmers may prefer to treat small batches at the time of their need where straw feeding may be relevant only in a particular season.

- **Compactability of straw**

This factor decides about the duration because it determines the storability of treated straw. Wheat straw in India is generally chopped and compacts very well at the time of storage. Mould growth is then substantially less than in case of the relatively loose rice straw. Mould growth has sometimes been observed in stacks of rice straw in both India and Sri Lanka, particularly when the straw is kept more than a few weeks, when the ammonia escapes or when the straw is too wet.

- **Ambient temperature**

The ambient temperature affects the rate of reaction of ammonia treatment as shown for Norwegian conditions by Sundstøl *et al.* (1978). The slow dissociation of urea might be responsible for that. Since temperature ranges with altitude, season and distance from the equator, it is possible that duration of treatment in winter from December to February needs to be longer in Northern than in Southern India. But it is important to distinguish between ambient temperature and stack temperature. The stack temperature not only depends on ambient temperature but also on stack size, moisture content, compaction or sealing methods. Even in the cooler November months in Northern India or Pakistan, the ammonia smell starts to develop within a few days, together with an increase of temperature inside the stack, leading one to conclude that under those circumstances duration of treatment needs to be very short.

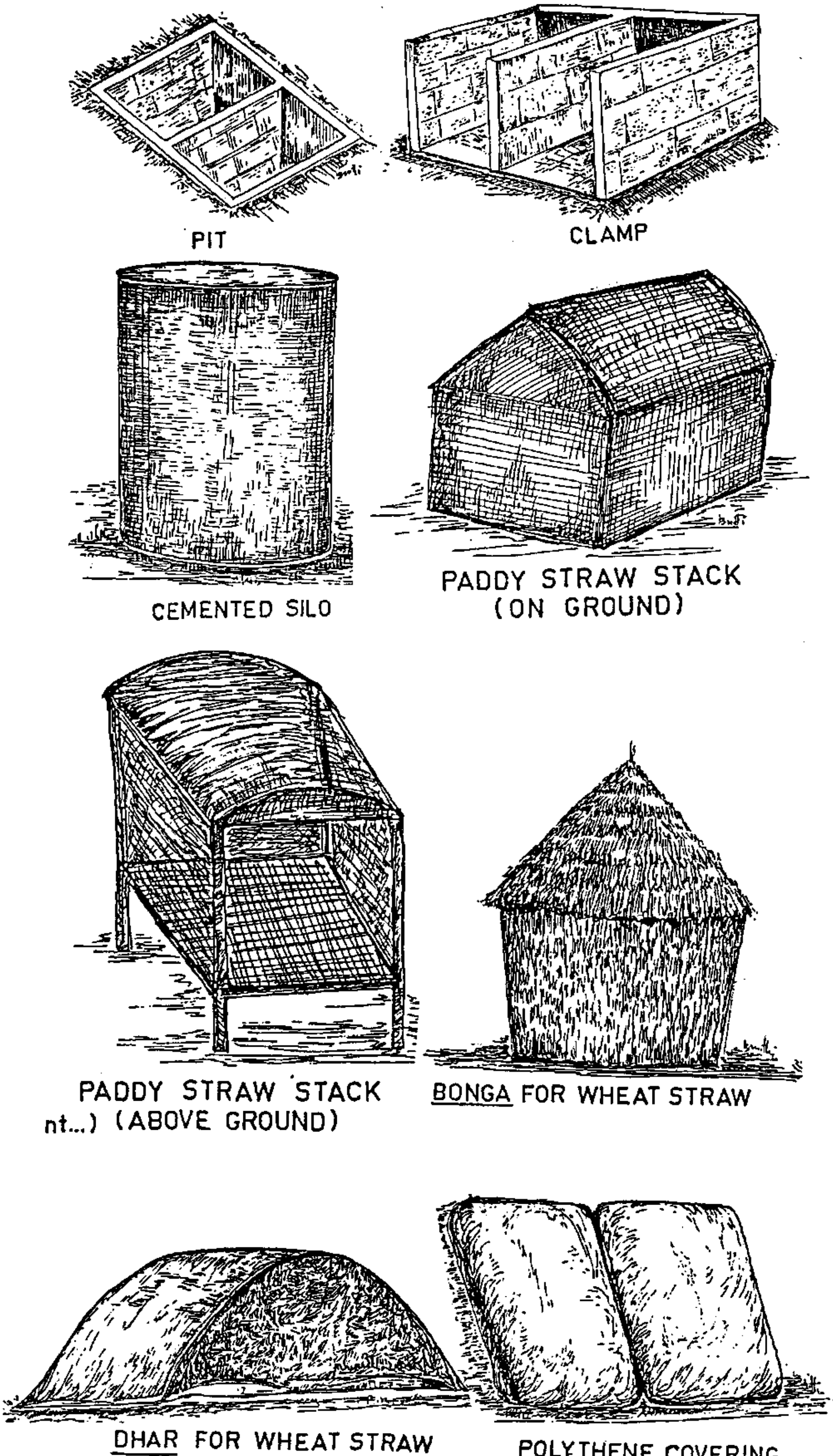
- **Addition of urease**

Urease has been used to accelerate the urea conversion process (Jayasuriya and Pearce, 1983; Ibrahim, 1985; Kumarasuntharam *et al.*, 1983). Overall, the addition of urease complicates the treatment process and seems to have little practical value for treating straw with urea.

Storage structures

The use of storage structures for straw treatment play a key role in the economics and practicality of treatment technology, in addition to the efficiency of ammoniation process. The storage structures as prevailing in India have been classified into different groups. Most farmers prefer to construct their own storage structure depending on availability of infrastructure and economic considerations (Figure 1).

Figure 1 Different storage structures for straw treatment (for explanation of twin pits see text)



Airtightness during storage is generally considered as a prerequisite for obtaining maximum effect of urea-ammonia treatment. The work carried out in Bangladesh in which rice straw was ensiled with a urea solution in earthen pits or bamboo baskets using banana leaves to avoid contamination of the straw with soil and covering the tops with local material such as jute bags, mud and cow dung plastering to avoid ammonia losses gave good results (Saadullah *et al.*, 1981). The importance of airtightness has been a matter of debate and is also discussed by Rao *et al.* (1993). The conclusion seems to be that especially for the smaller stack, it improves the process efficiency. In Sri Lanka Ibrahim *et al.* (1983) compared various types of storage structures of urea-ammonia treatment of straw and found that earthen pit stands best amongst all other types followed by polythene bags in terms of both dry matter intake and digestibility (see Table 5). Other Sri Lankan work is presented in Table 8.

Many systems of storage are used in India depending on type of straw and the local conditions. Long straw like from rice in the North and fingermillet and sorghum in the South are stored in stacks, whereas chopped straw like wheat "Bhoosa" is stored either in a room, a bonga or a dhar, especially in the Gangetic plains. Both the bonga and dhar provide air tight conditions after mud and/or cow dung plastering. The use of polythene covering for treated straw as compared to open stack is efficient (see Tables 6 and 7) but costs money. Alternate covering like urea-bags could be suggested to achieve at least partial airtightness of the stacks. Rao *et al.* (1990) observed that the feeding value of rice straw (long) on urea-ammoniation and stored in airtight condition was better than that of straw stored in open stacks in terms of higher feed consumption and improved nutrient utilization. However, such response of urea-ammonia treatment of fingermillet straw was not obtained (Rao *et al.*, 1993). Recent work indicates that wheat straw could be stored even in a room without covering after urea treatment for ammoniation (Rai and Aggarwal, 1991). Since wheat straw compacts well the reaction is complete and can be compared with any other system of storage (i.e. of covering with polythene/or mud plaster).

A twin pit or clamp system for a continuous supply of straw treated for a limited time has proven to be practical for some systems, including some in India. The choice for using a twin pit or a clamp system versus a large stack at once for ammoniation depends on the number of animals and the daily straw requirements. A twin pit or twin clamp method as described by Schiere and Ibrahim (1989) is suitable for small dairy owner/landless labour having a few animals alongwith small quantity of straw to be treated in batches as and when required. In this process family labour may be utilized for the treatment and stored in a limited space, whereas the large stack system with all straw treated at once may be suitable for those farmers who produce a large quantity of home grown straw having large number of animals and no monetary constraints may use this method.

A general comment is that a pit in the ground may seem attractive because it seems cheap and easy to construct or to dig. However, problems with such systems are: contamination of straw with soil and seepage of water from the side of the pit, especially during the rainy season. Moreover, the pit is difficult to fill or to unload, and rocky land may not be suitable for digging pits.

Table 5 DMI and vivo digestibility as affected by types of storage structure (Ibrahim *et al.*, 1984)

Particular	Pit	Polythene covering	Urea bags	Clamp	Open
(VIVO) DMD (%)	61.1	59.5	57.2	57.5	53.0
DMI (% of BW)	2.98	2.86	2.63	2.14	2.43
DDMI (% of BW)	1.82	1.79	1.51	1.23	1.29

Table 6 Effect of different storage methods of ammoniated paddy straw on CP, DMI and digestibility (Reddy *et al.*, 1989)

Particular	Untreated	Open Stack	Pit with Polythene
CP (%)	3.4	6.8	8.8
DMI (kg/100 kg BW)	2.2	3.0	2.9
OMD (%)	45.7	53.2	57.0
TDN (%)	38.0	43.0	47.0

Table 7 Effect of covering with or without a PVC line structure of ammoniated wheat straw on performance of animals (Chaturvedi, 1988)

Particular	Open clamp without PVC Lining (3% area)	Closed clamp with PVC Lining (3% area)
CP (%)	6.80	8.80
DMI concentrate (kg/day/animal)	1.20	1.00
DMI straw (kg/day/animal)	1.80	2.15
DMI straw (kg/100 kg BW)	1.40	1.60
DMD straw (%)	47.80	49.90
Daily gain (g/day)	291	317

Sealing of storage structures

The main purposes of sealing the treated straw are to protect the stack from rain water, to retain the ammonia in the stack and to avoid a loss of moisture from the stack. In case of small stacks of uncompacted rice straw, the air tight sealing is more essential than for similar sized or larger stacks of well compacted wheat straw. Losses occurring from the sides are relatively larger for small stacks and mould growth is often seen. Ammonia losses are considered to be a waste of resources. Particularly in case of small stacks the cost of sealing material is not very high, particularly when the sealing material can be used repeated-ly in the case of short duration of treatment. Large stacks of well compacted straw such as wheat straw or even neatly bundled rice straw incur lower side losses or evaporation of ammonia. The experimental data about the use of sealed versus non sealed straw (see Table 8) show that complete airtightness is always better, though open treatment is always better than no treatment, particularly if the straw is treated for a short duration and in large stack.

Table 8 Differences between closed and open system of storing systems of treated straw as measured by animal performance

System of storing treated straws (% of BW)	Days	Straw DMI (% of BW)	LWG (g/day)	Source
Closed	9	2.9	310	Perdok et al., 1984
Open	9	3.0	282	(local bull)
Closed	9	3.0	307	Kumarsuntharam et al., 1984
Open	9	3.3	207	(local bull)

The type of sealing material is also not uniform. The cost of polythene can be quite high or even prohibitive unless only small amounts are used repeatedly to cover small batches for a short period, rather than one large stack for a larger duration as in the twin pit system. Traditional sealing methods such as mud plastering on wheat straw are well known in Northern India (U.P., Haryana, Punjab) but will not work for rice straw which is more loosely stacked. The polythene lining of urea bags (see Table 9) or even gunny bags themselves may be used as well as other alternatives such as grass mats, mud plaster, bamboo baskets or bonga. The best recommendation about duration and way of stacking depends on the particular farmer and the prevailing farming system.

Table 9 Effect of open and covered stack of ammoniated forest grass on performance of animals (Pradhan, unpublished)

Particular	Open stack	Covered stack with polythene lining of urea bag
DMD (% of NBDMD)	52.0	57.0
DMI (% of BW)	2.65	2.56
Daily gain (g/day)	221.0	304.0
Feed conversion ratio	21.7	17.1
Feed cost/kg gain (INR)	23.0	18.0

The large variability of farming systems in India requires different adaptation of treatment systems and boxes 1 and 2 show how treatment is done in Gujarat and Karnataka.

Box 1 Straw treatment in Gujarat (BAIF experiences P.K. Pradhan)

Gujarat (experiences BAIF)

Trials on treatment wheat, rice or maize straw, and local/forest grass in various parts of Gujarat state, was done as follows:

- 4 kg urea dissolved in 40 l of water to be sprinkled over 100 kg of straw;
- small stacks of 250 - 1000 kg straw were made and the urea solution was spread uniformly on straw, while stacking layer by layer;
- untreated dry grass and/or straw, empty fertilizer bags, cattle feed bags or plastic sheets are used
- garden sprinkers or a tin with small holes at the bottom was used for uniform spread of the urea solution;
- the period of treatment was up to 21 days;
- the percentage of moisture depends upon the season. In summer when the temperature is very high, we used 50 liters of water for 100 kg of straw, but 30 - 40 liters were also used;
- small stacks of straws are recommended because they:
  * are more practical for small farmers;
  * require less material, such as urea, plastic cover and water;
  * require less labour;
  * less area for storage;
  * are better suited to the small animal holding, i.e. fodder requirement is less.

Box 2 Straw treatment in Karnataka (experiences A. Kumar)

On-farm animal trials of urea treatment of rice straw in small and urban areas were done as follows:

- 4 kg urea dissolved in 100 l water as sprayed over 100 kg rice straw;
- about 700 - 1000 kg treated straws were stored in chambers of cement rings, for a period of 7 days;
- rose can was used for spraying urea solution layer by layer;
- effectiveness of treatment was achieved by trampling the straw layers. The covering was done with used urea bags and placing stones over them;
- feeding of treated straw was done in wet condition by stacking them in a gunny bags (12 -15 kg wet straw) and fed at intervals;
- this system worked well for rice straw.

SPECIAL ISSUES

Sometimes fungi or mould can develop in the stack, when straw is kept for a long time or when the initial straw quality is poor e.g. because of moist or dust. Ammonia is considered to act as a fungicide, and it is actually used for preservation of moist straw in Norway. Some fungi can tolerate the ammonia (Singh *et al.*, 1993) and loss of ammonia may also allow other fungi to grow. This is mainly due to poor compaction, too much water, poor initial straw quality or contaminated straw with soil. The pattern of occurrence is not always predictable. The incidence of mould increases as the duration of treatment extends. Better sealing and compacting certainly reduces the incidence of moulds. Moulds of different kinds can be either beneficial or harmful, but preferably, feeding of mouldy straw should be avoided. When straw is stored in moist conditions it may be advisable to stack it on a platform to avoid infestation with termites etc., as is done in large areas around Bangalore.

Quality and species/cultivar of straws

Treatment of straw is potentially more effective when the initial straw digestibility is low (Rai and Mudgal, 1989; Prasad *et al.*, 1993). One explanation is that there is not much to improve in a straw with an already high digestibility. Another explanation is that the chemical treatment acts on the indigestible cell wall constituents, i.e. a high initial digestibility implies less cell wall constituents that can be affected by treatment. Though treatment may have more effect in poor than in good quality straws, it generally does not alter the ranking of the straws after treatment. Quality of straw refers here to initial digestibility, not to freshness or dryness. When the straw is mouldy or spoilt before treatment, the final result of treating such straw is worse than without treatment. All straws respond similarly to treatment, though the mechanisms may be different (Prasad *et al.*, 1993).

Farmers are understandably concerned with health and reproduction of their animals as well as with the immediate/long term effects of straw treatment on the milk production. Though long term effects on health are difficult to assess, there seem to be no indications of negative effects (Singh et al., 1993; Sewalt and Schiere, 1989). In Ranipet (Tamil Nadu), one dairy farm is using treated straw for over 2 years without any adverse effect on production performance as well as fertility status of the cows (Kumar et al., 1993).

CONCLUSIONS

The application of straw treatment is necessarily different from one farming systems to another. Considerable agreement exists on level of urea and amount of water to be used for urea-ammonia treatment of rice and wheat straw, i.e. 4% urea and around 50 l of water per 100 kg of straw. Aspects such as duration of treatment, type of storage and requirement for air tight sealing are to be decided on local level and depend on type and compactability of straw, availability of labour, cost of materials and size of operation. It will be unwise to force the extension service into a uniform national recommendation. It appears to be agreed that negative effects on animal performance and health are unlikely, especially when feeding of treated straw is compared with that of untreated. The testing of urea treatment as developed for wheat and rice straws needs to be encouraged for other straw stovers like fingermillet, sorghum, maize and pearl millet. Further research should be concentrated on so-called dose-response experiments in which trends can be better analysed.

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PHYSICAL, CHEMICAL AND MORPHOLOGICAL CHARACTERISTICS OF SLENDER AND COARSE STRAWS AND RESPONSE TO UREA TREATMENT - A REVIEW

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SUMMARY

A comparison of treatment effect on straws requires a classification of straws into coarse, slender and rice straws. The coarse stemmed straws (fingermillet, sorghum, pearl millet and maize stovers) differ from slender stemmed straws (rice, wheat, barley and oats) though rice could be considered as a separate category, with respect to physical, chemical and morphological characteristics. The coarse straws have a higher leaf: stem ratio than slender straws. The stems of coarse straws are smooth, waxy and pithy, whereas those of slender straws are rough and hollow. The millet (coarse stemmed) straws have a higher nitrogen content (0.5 - 1.20%) and higher cell solubles (16 - 37%), than slender stemmed straws (0.24 - 1.08% N and 4 - 22% cell solubles). These differences could influence the intake of straws due to selective consumption by the animals. The DM intakes and nutrient digestibilities of coarse straws are higher than those of slender straws. The NDF digestibility is in the order of leaf blade > leaf sheath > stem for both coarse and slender straws, indicating that NDFD is higher in leaf. Both the coarse and slender straws respond to urea treatment, however a varied response was observed when the millet and sorghum straws were subjected to urea treatment in laboratory conditions. Under practical feeding a marked improvement in DMI from 58 g/kg $W^{0.75}$ in untreated fingermillet straw to 77 g/kg $W^{0.75}$ in treated straw is observed. An increase of approx 15 - 20 percent in the DMD and OMD of treated millet straws is noticed. The response to urea treatment seems to be greater with straws of low initial digestibility than those having better digestibility values.

INTRODUCTION

A comparison of the effect of treatment on straw quality requires a categorization of straws into particular "classes" viz.:

- the thin or slender stemmed straws like rice, wheat, barley and oats;
- the thick or coarse stemmed straws like sorghum, finger-millet, pearl millet and maize stovers.

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The literature on nutritive quality of the coarse straws is limited. The coarse straws vary considerably with respect to physical, chemical and morphological characteristics as compared to slender straws. Rice straw is usually grouped with the slender straws, but it can also be considered as a seperate category, due to peculiar properties as will be seen later. Among others, rice stores sugars as starch in stem, while other grains use sugars as fructans (Singh and Oosting, 1993).

The nutritive value of straws is determined by their concentrations of digestible nutrients, DMI and the efficiency of the utilization of absorbed nutrients. The utilization of cell wall components is influenced by species and variety of straw and the agroclimatic conditions under which it is grown. The DMI depends on plant characteristics of the plant such as texture, smell and taste which may affect straw acceptability (Kenney, 1984; Colebrook *et al.*, 1990; Kenney and Black, 1984; Prasad *et al.*, 1993).

The physical and morphological characteristics with respect to the stem nodes, leaf : stem ratio and stem surface differ between the slender and coarse straws. The chemical characteristics like N content, cell wall content (NDF) and presence of cell solubles also seem to vary between these two classes of straws, which could affect intake and digestibility. However, in rice straws the NDF content varies widely (54 - 86.1) and they have the highest silica content (8 - 13.1) as compared to other slender straws. NDFD of various plant fractions is higher for leaf blade suggesting better digestibility of leaves in both coarse and slender stemmed straws, with some exception for rice straws. Various methods are available to improve the nutritional value of straws (Sundstol and Owen, 1984) and include physical (Oji and Mowat, 1978; Rai and Mudgal, 1985), chemical (Rai and Mudgal, 1986 1987 a,b; Shariff and Gupta, 1987) and biochemical treatments (Rai and Mudgal, 1983, 1984), supplementation (Preston and Leng, 1987; Schiere *et al.*, 1989) or improvement through breeding (Reed *et al.*, 1988a) and cultural practices (Berger *et al.*, 1979). Urea ammoniation of straws appears to have potential to increase the feeding value of slender straws (Owen and Jayasuriya, 1989; Schiere and Ibrahim, 1989) as well as of coarse stemmed straws (Prabhu and Subba Rao 1988; Joshi *et al.*, 1988; Prasad *et al.*, 1990a, b). The response to treatment varies depending on the initial quality of the straw (Kumar *et al.*, 1988) and the level of urea applied (Prasad *et al.*, 1990b; Joshi *et al.*, 1988).

This paper reviews the nature of straws with respect to their:
(1) physical, morphological, chemical characteristics,
(2) digestibility of the different plant fractions,
(3) feeding value in relation to feeding for maintenance,
(4) the effect of urea treatment.

Physical and Morphological Characteristics

The slender and coarse straws belong to the monocotyledon group and the slender stemmed straws follow the C_3 and C_4 pathway and the coarse straws pre-dominantly C_4 pathway. The major differences on the biochemical pathways for C_3 and C_4 plants that might influence quality have been discussed by Norton (1984). Tropical grasses contain more vascular bundles than temperate grasses (Norton, 1984) and the other common feature is their low leaf : stem ratio due to continuous elongation and flowering throughout the growing season ('t Mannetje, 1986).

Some of the physical and morphological characteristics of the two straw classes are presented in Table 1. The straws of rice, wheat, barley, oats and rye have a similar range in morphological composition. They have variable numbers of nodes from where the leaves arise. Except for rice which has 10 - 20 stem nodes (Norton, 1984) other slender straws have 5 - 6 stem nodes. Due to more stem nodes, rice straw has a higher percentage of leaves. This higher leaf percentage cannot be used for extrapolation about straw quality because rice leaves are sometimes of higher digestibility than stem (Aman and Nordkvist, 1983) but at other times are of lower digestibility (Doyle *et al.*, 1986).

The straws of sorghum, fingermillet, pearl millet and maize stovers also have a variable number of internodes separated by nodes. The coarse straws have more stem nodes (10 - 15) as compared to slender stemmed straws. The leaf : stem ratio is higher in coarse straws (0.7 - 0.9) as compared to slender straws (0.4 - 0.8) with the exception of rice. The stems of slender straws are rough and they are hollow, whereas those of coarse straws have smooth and waxy surfaces with a solid stem pith. The smooth outer surface observed in millet and sorghum straws causes problems because water does not adhere or absorb well into the straw as usually observed during urea-treatment of these coarse straws (Kumar *et al.*, 1987; Joshi *et al.*, 1988). On the one hand, the smooth surface would pose a problem for (urea) treatment of unchopped straws from these coarse grains. But in the chopped form moisture uptake would be more due to pith. This has two implications:

(i) lower loss of moisture and/or nitrogen,
(ii) high moisture retention could deteriorate the straw quality.

The leaf to stem ratio affects the feeding value of the straws as the digestibilities of these two components differ significantly (Doyle *et al.*, 1987). The lignified straw tissues are mainly present in the outer ring of the internodes making it resistant to microbial degradation, whereas in leaves the lignified tissues are separated from each other making the mesophyll cells more easily available for microbial attack (Van Bruchem and Soetanto, 1987). The nodes are more easily degraded by micro-organisms than the internodes (Harper and Lynch, 1981). In tropical grasses with a C_4 pathway the parenchym bundle sheath

Table 1 Physical and morphological characteristics of slender and coarse stemmed straws

Plant species	Stem nodes	Leaf : Stem	Stem surface	Stem morphology	Photo synthetic pathway
Slender straws					
Rice	10 - 20	1.06 - 1.76 (1.41)	Rough	Hollow	C_3 & C_4
Wheat	5 - 6	0.42 - 1.02 (0.72)	"	"	C_3 & C_4
Barley	5 - 6	0.53 - 0.62 (0.57)	"	"	C_3 & C_4
Oats	5 - 6	0.65 - 0.77 (0.71)	"	"	C_3 & C_4
Coarse straws					
Pearl millet	10 - 15	0.82 - 0.91 (0.87)	Smooth & Waxy	Solid pith	C_4
Sorghum	14 - 17	0.73 - 0.84 (0.80)	"	"	C_4
Fingermillet	12 - 15	0.66 - 0.87 (0.76)	"	"	C_4

Table 2 Physical features (grinding energy, J/g DM) of different parts of rice and wheat plants

	Rice straw	Wheat straw
Stem	168	197
Leaf sheath	94	112
Leaf blade	84	70

Source: Doyle et al. (1987)

is a rigid thick wall structure and whatever rapidly utilizable starch is protected in the rigid sheath structure is not available for rumen microbes unless the bundle sheath is damaged (Akin, 1986). However these straws have hardly any starch left. Lignin is part of the cell wall and is generally assumed to have a negative effect on digestibility, though its effect is controversial (Theander and Aman, 1984), which will be discussed in the rumen model (G.P. Singh *et al.*, 1993). Not all lignin is undegradable e.g. in maize, lignin in the middle lamellae was undegradable but not in primary and secondary cellwall (Engels, 1989; Wilson *et al.*, 1991).

The resistance of the plant material to physical breakdown affects intake (Doyle *et al.*, 1987). This occurs due to the selective retention of large particles in the reticulo-rumen. The efficiency of particle size reduction due to chewing and rumination of these straws could be important. Further the taste and texture of feeds may affect their acceptability by animals (Weston, 1985). Plants which cause abrasiveness while chewing are less preferred; which is true with silicious forages (Van Soest, 1982). The selection of leaf components by animals is mostly due to their physical nature rather than higher digestibility (Hogan *et al.*, 1986). The energy required for physical breakdown by grinding, may vary from about 30 kJ/kg DM in temperate leafy pastures to 550 kJ/kg DM in tropical grasses (Weston and Poppi, 1987). This could be as high as 20% of the digestible energy. In the case of rice and wheat straw the grinding energy of leaf blades is lower than that of leaf sheath and much lower than that of stems (Doyle *et al.*, 1987) (see Table 2). In the case of rice straw, the differences between plant components are smaller than for wheat straw.

This could possibly be attributed to the high silica content of rice straw leaf sheath and blades which is twice that of stems and may limit its acceptability. A positive correlation between silica content and grinding energy has been observed in case of rice straw, but not so in the case of wheat straw (Doyle et *al.*, 1987). The low grinding energy required for leaf blades indicates that the leaf material may be more acceptable to animals than stem and this is true in case of barley straw (Wahed and Owen, 1986) and for oat straw (Ibul *et al.*, unpublished data). Similar studies in the case of coarse straws are limited and much work needs to be done, though indications are that the leaf blade portion of coarse straws are more digestible (Subba Rao *et al.*, 1990) than the stem. The differences in 48 hour digestibility of leaf and stem are small, but the rate of degradation is always higher for leaf than for stem in sorghum (Joshi *et al.*, 1988). It was also observed that the leaves of sorghum straw were less palatable in some 'bird resistant' varieties, possibly due to the presence of phenolic compounds (Reed *et al.*, 1988b).

The variations in the physical and morphological characteristics between straw types may be partly due to the cultivars, managemental practices and agro-climatic conditions as elaborated in session 5 in these proceedings. More data are required to determine the effect of these characteristics on the acceptability of different plant parts by animals for both slender stemmed and coarse stemmed straws.

Chemical characteristics

Recent studies show significant variations in OMD in both slender and coarse straws. The variations are partly explained by NDF and NDFD (Deinum, 1988; Badve *et al.*, 1993; Subba Rao *et al.*, 1993). The NDF is affected by the growing conditions, variety and maturity of the crop. Grainfill affects NDF content, since grainfill is inversely related with NDS. Genetic effects on DMD or OMD in most of the slender stemmed and coarse straws have been shown. Variety trials have shown differences in the OMD of barley, oats, rice and wheat straw (Doyle *et al.*, 1986, 1987) of sorghum straws (Schmidt *et al.*, 1976) and of fingermillet straws (Subba Rao *et al.*, 1993).

A wide variation exists within the straws, which could be partly due to the cultivation practices. The chemical composition of the various straws is presented in Table 3. N content is highest in legume straws (0.8 - 1.2), followed by coarse stemmed straws (0.5 - 1.2) and slender straws (0.24 - 1.0). The crude protein levels in the slender and coarse straws are far below the critical level of 7% dietary CP required for acceptable voluntary feed intake (Van Soest, 1982; Le Trong Trung, 1986). This is discussed by Walli *et al.* (1993). An inadequate supply of N retards microbial growth and thereby affects the degradation of cell wall components and hence feed intake.

The NDF content also varies markedly within the straw species and decreases in the order of slender straws > coarse straws > legume straws. The organic cell solubles are higher in millet and sorghum straws (16 - 37%) as compared to rice and wheat straws (4 - 22%). The NDF content and OM digestibility of the whole plant may not give a clear picture of the straw value, as it does not give much information on the quality of cell walls, and it is necessary to look into the NDFD (Table 4). The NDFD of leaf blade and leaf sheath are higher than of stem in both slender and coarse straws, again with an exception for rice straw where it can go either way. The difference in the NDFD of leaf and stem indicates that they have different cell types. Lignin in NDF of stems of wheat, barley and oats is higher than in leaf. The higher contents of N, and cell solubles and lower silica content of coarse straws are associated with higher intakes (64 g/kg $W^{0.75}$) compared to slender straws (40 - 52 g/kg $W^{0.75}$) with the exception of rice straw (Prasad *et al.*, 1993). Though the coarse

Table 3 Range in Chemical composition of crop residues (% DM)

Crop residues	N	OM	NDF	Lignin	Silica
Rice straw	0.4 - 1.0	76 - 90	54 - 86	4 - 12	8 - 13
Wheat straw	0.24 - 0.78	90 - 96	75 - 83	8 - 10	4 - 6
Barley straw	0.35 - 1.04	90.8 - 92	77 - 82	6 - 9	4 - 6
Oats straw	0.54 - 1.08	91 - 94	70 - 72	8 - 9	3 - 4
Pearl millet straw	0.75 - 0.93	90 - 96	68 - 70	6 - 7	3 - 4
Sorghum straw	0.62 - 1.02	89 - 93	56 - 71	6 - 10	4 - 5
Fingermillet straw	0.50 - 1.2	85 - 93	72 - 78	5 - 10	3 - 6
Maize stovers	0.8 - 1.0	92 - 94	65 - 68	9 - 11	3 - 4
Gram straw	0.9 - 1.0	94 - 96	55 - 57	8 - 10	3 - 4
Mung straw	0.9 - 1.2	90 - 92	40 - 43	4 - 6	6 - 8
Guar straw	0.7 - 0.85	92 - 95	40 - 43	4 - 6	1 - 2

Table 4 Cell wall digestibility (NDFD) of different plant parts (%)

Straw	Leaf blade	Leaf sheath	Stem	Reference
Rice*	56	40	33	Doyle et al., 1987*
Wheat	43	46	28	Doyle et al., 1987
Fingermillet	55	-	35	Subba Rao et al., 1993
Sorghum	60	50	55	Badve et al., 1993
Pearl millet	60	42	31	Badve et al., 1993

Note: * In some cases the cell wall digestibility of stem of rice straw is more than the leaf blades (ref.)

straws are marginally superior in their digestibility than slender straws, their utilization may still be improved by treatment, which will be discussed in the course of this paper.

The chemical composition of the straws plays a significant role in their intake and digestibility, particularly the N content, cell wall content and cell types of different plant parts and their digestibility as elaborated by Singh and Oosting (1993) and the presence of anti-nutritional factors like silica, lignin, tannins and oxalates.

It is for the nutritionists and plant breeders to decide whether the selection of varieties should be based on:
- high digestible fractions of the plant (for example more leaf);
- higher cell solubles;
- more digestible cell walls.

To answer some of these questions more work needs to be done on the chemical and morphological characteristics of different plant parts of different cultivars grown under different agroclimatic conditions and management practices as discussed in session 5 on variability.

Straws in relation to feeding for maintenance

Straws of good quality might meet the energy requirement for maintenance of adult ruminants, while poor quality straws fall short of meeting the requirement (Doyle *et al.*, 1986; Prabhu *et al.*, 1988). The physiological status of the animal and variation in straw quality are very important determinants for intake (Joshi *et al.*, 1991). But it can be assumed from the various research findings that on average cattle consume about 65 g DMI/kg $W^{0.75}$ when fed rice straw alone (Prasad *et al.*, 1993). Hence it can be calculated that it is not possible to consume sufficient energy from rice straw to meet maintenance requirements (see Table 5). When cattle and buffalo consume 89 g/kg $W^{0.75}$ (DMI 2% BW) from rice straw, which is high but not impossible, then the animals will be consuming sufficient energy to meet their maintenance requirements (Kearl, 1982). The sheep and goats, using the same assumptions are unable to consume enough straw DOM for maintenance. Wanapat *et al.* (1984) and Wongsrikreau and Wanapat (1985), observed that even when cattle consumed rice straw alone at 89 g/kg $W^{0.75}$ (DMI 2% BW), they lost weight. This can be because:
- the live weight changes may be a reflection of lower gut fill which was not measured in these trials;
- the efficiency of use of the absorbed energy was limited due to an inadequate supply of other essential nutrients;
- the straw was of a relatively poor quality.

It may be interesting to note that coarse straws like sorghum and millets are more likely to supply maintenance requirements for cattle (Table 5) than for sheep or goats.

Table 5 Energy for maintenance from straw for cattle and sheep

Species	Body (kg)	MBW (kg)	DMI (g/kg MBW)	DMI % BW	TDMI (kg)	DOM (kg)	Required DOM (kg)	Straw type
Cattle	400	89.4	65	1.45	5.8	2.09[+]	2.97	rice
Sheep	40	15.9	40	1.60	0.64	0.23[+]	0.41	rice
Cattle	400	89.4	64	1.42	5.7	2.90[++]	2.97	sorghum
Cattle	400	89.4	66	1.46	5.84	2.94[++]	2.97	fingermillet

Notes: [+] Calculated assuming OM 80% and OMD 45%
[++] OM 90% and OMD 56%

It is apparent that it is necessary to supplement straw diets with (readily available) energy and other deficient nutrients (proteins, minerals etc.) to meet the maintenance/production requirement. As differences in straw digestibility among cultivars have been reported for barley (Lufadeju *et al.*, 1985; White *et al.*, 1981), oats (White *et al.*, 1981; Haque *et al.*, 1981), rice (Roxas *et al.*, 1985; Hart and Wanapat, 1985), wheat (White *et al.*, 1981), sorghum (Badve *et al.*, 1993) and fingermillet (Subba Rao *et al.*, 1993) it may be worthwhile to consider improvements in the feeding value of straws through breeding programs or better management, which is receiving attention in part 5 of these proceedings.

Urea-ammonia treatment of straws

Approaches to overcome the problems of the low nutritive value of straw include physical and/or chemical treatment. Urea ammonia treatment of straws is one of the most promising methods for improving their feeding value.

The effect of urea ammonia treatment of both slender straws and coarse straws is presented in Table 6. The effect of treatment also appears to be largest on straws with lowest initial digestibility (Figure 1). Urea-ammoniation improves rice straw from a submaintenance diet to a maintenance diet for cattle and buffaloes (Lohani *et al.*, 1987; Wanapat *et al.*, 1984; Wongsrikeau and Wanapat, 1985; Ghebrehiwet *et al.*, 1988). The treatment improves DMI by 7 - 20 units and digestibility by 4 - 15 units. The increase is not uniform, probably due to differences in the initial quality of the straw, type of treatment, straw variety and the physiological status of animals.

The treatment improves DMI and digestibility of rice straw in sheep and goats also to the tune of about 11 - 17 units (Trung *et al.*, 1987; Djajanegara and Doyle, 1989). Similar responses of wheat straw (Harrera-Saldana *et al.*, 1982; Phukan and Singh, 1983, Singh and Gupta, 1987), barley straw (Horton, 1978; Mira *et al.*, 1983) and oat straw (Horton, 1978, 1981) to treatment has been recorded. In general treatment is found to increase OMD from 42 - 43 percent to 45 - 60 percent for rice straw, from 42 - 48 percent to 43 - 60 percent for wheat straw respectively. By improving the intake and digestibility through treatment, it is possible to meet the energy requirements for maintenance of adult cattle as discussed earlier. However, it is essential to have additional supplements when requirements for higher levels of production are to be met. As long as straw remains a major part of the diet, urea treatment has shown to have substantial advantages over untreated slender straws (Doyle *et al.*, 1986). Several trials (Saadullah *et al.*, 1983, Jaiswal *et al.*, 1983; Karunaratne and Jayasuriya, 1984; Kumar *et al.*, 1988; Djajanegara and Doyle, 1989; Schiere and Wieringa, 1988) have shown that urea supplementation is not to be as effective as urea treatment, though the effect is often confounded with level of urea (see Figure 3 in: Schiere and Ibrahim, 1986).

With coarse straws (millet and sorghum) the energy requirement for maintenance in cattle and buffaloes can almost be met (Table 5) and further improvement in intake and OMD due to treatment could be beneficial in meeting to some extent the production requirement, provided other nutrients including minerals are adequate. By feeding treated straws instead of untreated, the quantity of concentrate can be reduced, the economics of which depend on the level of production and the costs of straw, supplements and price of produce (Schiere *et al.*, 1988). Those issues are discussed in session IV by Kumar *et al.* (1993) and Singh *et al.* (1993).

Figure 1 Response of straws to treatments

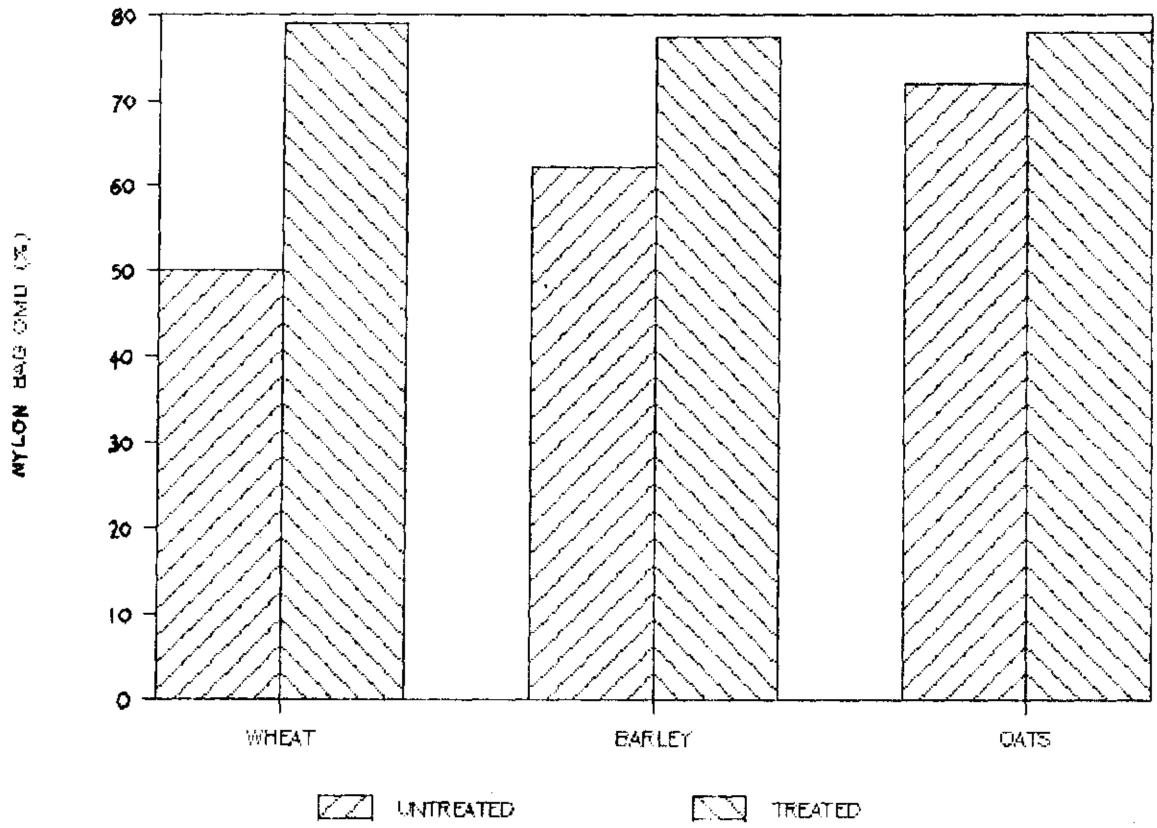

Table 6 Effect of treatment on quality of slender and coarse straws

Straw type	Animal	US/TS	DMI	DDMI	DOMI	DMD %	OMD %	IVOMD %	Reference
Rice straw	Goats	US	52.1[a]	187[b]	-	-	-	43.9	Trung et al.(1987)
		TS	63.5[a]	373[b]	-	-	-	50.5	
Rice straw	Cattle	US	84.0[a]	35.58[a]	-	42.21	-	47.2	Lohani et al.(1987)
		TS	115.0[a]	50.76[a]	-	44.18	-	52.9	
Rice straw	Cattle	US	1.9[c]	-	0.86[c]	42.0	52.4	-	De Rond (unpublished data)
		TS	3.1[c]	-	1.56[c]	46.0	56.8	-	
Rice straw	Buffalo	US	80.0[a]	-	-	43.0	-	-	Wongsrikeao & Wanapat (1985)
		TS	90.0[a]	-	-	53.0	-	-	
Rice straw	Cattle	US	67.7[a]	-	-	42.0	47.0	-	Borah et al. (1988)
		TS	79.4[a]	-	-	60.0	61.0	-	
Rice straw	Sheep	US	52.1[a]	-	-	41.0	-	-	Dolberg et al. (1981)
		TS	69.1[a]	-	-	54.0	-	-	
Rice straw	Sheep	US	-	-	-	41.5	47.5	-	Djajanegara & Doyle (1989)
		TS	-	-	-	53.6	61.0	-	
Wheat straw	Cattle	US	62.9[a]	-	-	39.6	41.7	-	Herrea Saldana et al. (1982)
		TS	71.2[a]	-	-	41.9	43.1	-	
Wheat straw	Cattle	US	63.8[a]	-	-	38.6	42.1	-	Phukan & Singh (1983)
		TS	80.7[a]	-	-	49.5	53.3	-	
Wheat straw	Buffalo	US	1.13[a]	-	-	-	-	-	Singh & Gupta (1987)
		TS	1.90[a]	-	-	-	-	-	
Wheat straw	Sheep	US	286[b]	-	-	-	-	-	Singh & Negi (1985)
		TS	289[b]	-	-	-	-	-	
Barley straw	Cattle	US	39.5[a]	-	-	48.8	-	-	Horton (1978)
		TS	52.8[a]	-	-	55.7	-	-	
Oat straw	Cattle	US	46.2[a]	-	-	48.7	-	-	Horton (1978)
		TS	61.9[a]	-	-	64.6	-	-	
Fingermillet	Cattle	US	65.0[a]	32.0[a]	-	49.3	52.4	-	Joshi et al. (1988)
		TS	87.0[a]	52.1[a]	-	59.9	63.1	-	
Fingermillet	Cattle	US	48.0[a]	-	-	49.0	51.0	-	Prasad et al. (1990a)
		TS	60.4[a]	-	-	62.0	64.0	-	
Fingermillet	Cattle	US	54.0[a]	-	-	51.8	55.0	-	Prasad et al. (1990b)
		TS	75.0[a]	-	-	69.0	72.0	-	
Sorghum	Cattle	US	51.0[a]	27.0[a]	-	53.1	55.4	-	Joshi et al. (1988)
		TS	74.0[a]	41.0[a]	-	55.2	59.4	-	
Sorghum	-	US	-	-	-	-	-	40.1	Pornsri Chairatanayuth
		TS	-	-	-	-	-	60.7	& VibhuvanWanamolee (1987)
Corn stover	Cattle	*US	3.31[d]	-	-	56.6	-	-	Saenger et al. (1982)
		*TS	4.09[d]	-	-	62.1	-	-	

Notes: [a] g/kg $W^{0.75}$; [b] g/day; [c] kg/100 kg BW; [d] kg/day; * with conc. supplement.

Favourable responses of fingermillet straw to urea treatment under laboratory scale studies were not observed (Kumar *et al.*, 1989). The different response is attributed to the pH modulation studies of FMS, which has an initial pH of 7.8 as against 6.5 of rice straw and the increase in pH after urea treatment is around 8.5 for both the straws. It appears that urea treatment of FMS did not alter cell wall content to any measurable extent, possibly due to poor reactivity to ammonia. *In vivo* experiments did not show any inhibition or lack of urease activity as the urea applied was completely converted to ammonia within 3 weeks of treatment. More coordinated studies on both *in vitro* and *in vivo* trials are needed with the same quality of straw. It may be different with crop residues containing very high soluble sugars as is seen in case of sugarcane tops. Joshi *et al.* (unpublished data) found that fresh sugarcane tops with a pH of 5.2 when ensiled with different levels of urea, recorded a maximum pH of 6.4. Also the OMD and NDFD of urea treated sugarcane tops declined from 64% to 57%. This apparent loss was attributable to the decrease of soluble untrients during ensiling, which were lost during oven drying of samples. The NDFD was also lowered as a result of ensiling with urea from 59% ot 53%. Most of the decrease in NDFD was due to ensiling even without the inclusion of urea, perhaps because of high temperaturs. Further studies indicated that most of the decrease in OMD occurred in the stem portion which mainly contains the soluble and fermentable nutrients. The decrease in NDFD was also observed to be more in the stem than the leaf fraction. These results suggest that urea supplementation is better than urea treatment in materials having a high content of fermentable solubles.

The economics of feeding treated straw is discussed at length by Kumar *et al*. (1993), but it is interesting to see that in one of the studies with treated coarse straw (fingermillet) a significant reduction in the cost of feeding (in terms of cost per kg TDN) was achieved (Table 7). The response to urea treatment within and between the slender and coarse stemmed straws varied significantly. In slender straws the maximum response to treatment was in the order wheat > barley > oats > rice and in coarse straws sorghum > fingermillet > maize stovers. But it appears that improvement after treatment was greater for straws with a lower initial feed value (Figure). The NBOMD in wheat straw which was about 45% on the untreated material increased to 75% after treatment, but the effect was considerably less in barley straw (to 72 from 60%), which had higher initial NBOMD in the untreated material (Rai and Mudgal, 1987c). In the case of fingermillet straws, the OMD increased by 15 units after

Table 7 Economics of feeding

Particulars	Untreated FMS group	4% urea-ammoniated FMS group	2% urea supplemented FMS group
Total DMI (kg)	4.32	5.25	3.76
DMI from			
a. Concentrate (kg)	1.54	1.17	1.33
b. Straw (kg)	2.78	4.08	2.43
Cost of feeding (INR)			
a. Concentrate (INR 2/kg)	3.08	2.34	2.66
b. Straw	1.94*	3.47**	1.89***
Total	5.02	5.81	4.55
Cost per kg DMI (INR)	1.16	1.11	1.21
TDN Kg /Kg DM	0.60	0.72	0.66
Cost per kg TDN (INR)	1.93	1.54	1.83

Notes: * Straw cost INR 0.70 per kg; ** Urea treated straw INR 0.85 per kg; *** Urea suppl. straw INR 0.78 per kg treatment and the improvement was less when the initial OMD of the untreated straw was higher (Prasad *et al.*, 1990b). IVOMD increased from 40% to 61% after treatment of sorghum straw (Pornsri Chauatanayuth and Vibhuwan Wanamolee, 1987), but IVOMD increased from 55% to 60% in treated sorghum (Joshi *et al.*, 1988). This agrees with Kernan *et al.* (1979) and Ramanzin *et al.*, (1986), but Ibrahim *et al.* (1989) found smaller treatment effects with poor quality varieties, indicating a more complex relationship between variety and treatment effects. It may be necessary to conduct further studies on this aspect, also to determine the cost benefit of treatment of different straws based on their initial quality.

CONCLUSIONS

Straws need to be categorized in different 'classes' based on their physical, morphological and chemical characteristics, to allow a useful discussion of the effect of treatments on straw quality. Differences exist in the physical and morphological characteristics of slender stemmed and coarse stemmed straws. A special category might be used for rice straw. The coarse straws have a higher leaf : stem ratio than slender straws. The coarse straws have a higher N content, more cell solubles and lower silica content, which may explain the higher intake of these straws as compared to slender straws, with the exception of rice.

The variation in the NDFD of different plant parts could be a true indicator of the quality of cell walls. The NDFD of leaf blade and leaf sheath are greater than stem in both 'classes' of straws. The grinding energy required for physical breakdown is much lower for leaves than stems. This could influence selective intake by animals.

Slender straws such as from rice and wheat as a sole feed in the diet of adult cattle cannot meet the energy requirements for maintenance. However, coarse straws such as from fingermillet and sorghum can almost meet the maintenance requirement of cattle and buffaloes due to the higher DMI and OMD. Sheep and goats fed at the rate of 2% of live weight do not receive enough nutrients from straw for maintenance.

Urea ammonia treatment seems to be the most promising and viable method to improve straw nutritive value. An increase in DMI and OMD has been observed with both 'classes' of straws. The response to treatment varies with the initial quality of the material. A higher response to treatment can be achieved generally if the initial quality of the straw was poor. In slender straws the response to treatment decreased in the order of wheat > barley > oats > rice. More information is required on the urea-treatment of coarse stemmed straws both under laboratory evaluation and with actual animal feeding experiments. The response to urea treatment and supplementation of different straw varieties and their economic feasibility needs to be worked out.

More detailed studies on the two 'classes' of straw with special reference to morphological, physical and chemical characteristics is required to be carried out. Data are particularly scant for coarse stemmed straws.

A better understanding of the differences caused by C_3 and C_4 pathway is required with respect to dry weight accumulation, digestibility and palatability. The role of anti-nutritional factors like silica, oxalates and tannins affecting nutrient availability and utilization needs further study. NDFD of different plant parts to know the different cell types present in leaf and stem for coarse stemmed straws needs to be studied in depth.

Aspects of management or the possibililty of breeding for more digestible cell walls needs attention.

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MODELING OF CROP-LIVESTOCK INTEGRATION: EFFECT OF CHOICE OF ANIMALS ON CROPPING PATTERN

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SUMMARY

Many small farmers that practise rainfed agriculture have low incomes and they are seasonally underemployed. Introduction of dairy animals on their farm increases the opportunity for employment and potentially adds to their income. This paper reports a study undertaken to design new farming systems with crops and dairy, for conditions which are representative of rainfed farming around Baroda in Gujarat. Linear programming was used to optimise the number, type and production level of animals that could be maintained on feed, from different cropping patterns. Also, the usefulness of feeding urea treated straw was tested. Two farm models were designed. The first model cultivated 1 ha sorghum, had access to freely available roadside grass and 3 kg concentrate, which gave a maximum total milk production per farm of 10.6 l/day by using animals of 8 l/day. Beyond a production level of 8 l per animal per day, the program selected cultivation of a cash crop (cotton) because animals with low individual production could utilize the grain straw. A higher animal production level implies that the poor quality feed cannot be used, i.e. the straw is not put to value and the straw plus grain loses its attractiveness as compared to cotton. Urea treatment of stover resulted in an increased total production of milk per farm and per animal. The magnitude of improvement due to treatment is low in animals producing less than 2 l milk per day, but larger at higher individual production levels.

The second model cultivated 0.9 ha of sorghum and 0.1 ha of Leucaena leucocaephala *with no grass. The number of animals was lower than in the first model, as insufficient DM was available. The production of animals almost doubled when the diet was supplemented with 3 kg concentrate. The total farm income increases with milk production, though at low levels the increases were small. The use of urea treated straw or supplementation with concentrate is most advantageous when fed to high productive animals. The mixed farming system is more remunerative than cash crops only, provided that the animal productivity is adjusted to the feed quality, in order to be able to utilize the available feed biomass.*

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INTRODUCTION

Many farmers with small landholdings in rainfed agriculture conditions have low farm incomes, and they are seasonally severely underemployed. Estimates for employment opportunities on rainfed crops vary from 100 - 200 man days/ha/yr, depending on the type of crop cultivated (Euroconsult, 1989). Thus a family of two adults is engaged in on-farm income generation activities for only a small part of the year. Inclusion of suitable dairy animals is reported to generate additional employment of 60 - 100 days, thus potentially adding to the income of the family depending on the productivity of the animal and on input/output prices in the particular farming system (Singh, 1987; Singh *et al.*, 1993). In order to maximize the farm income, the available resources must be identified carefully when selecting new crop and/or animal combinations. This paper describes a modeling excercise to design farming systems for the conditions of Baroda dist ict in Gujarat. The work represents an example of a branch of Farming Systems Research that is called New Farming Systems Development by Simmonds (1986). Whereas he reserves the term for field testing of entire new systems, we feel that it can also be applied to desk excercises to test the possiblities of new designs. It is a simplified and hypothetical model along the lines of work by Morrison *et al.* (1986) and Vijayalakshmi *et al.* (1993), that is done to determine the value of the introduction of known transferable technologies.

THE MODELS

This study aims to maximize family income by selecting an optimum combination of livestock and (cash) crop cultivation for rainfed conditions around Baroda, the agro-ecological zone 3 in Gujarat according to Ghosh (1991). The crops selected for the model were sorghum and cotton as these are the preferred crops of the region. Cotton is a cash crop that fits the agro-climatological conditions and that absorbs much labour. The transferable techniques tested in the model are:

- urea treatment of stover;
- supplementation of the crop residue diet with small amounts of forage.

Linear programming was used to maximize farm gross margins and to determine the:

- optimum number of animals that should be maintained;
- optimum total and individual cow production of milk that could be sustained with available feeds;
- effect of stover treatment or supplementation on these parameters;
- livestock options;
- total gross margins income generated.

The model was kept very simple, and details are available upon request from the authors. Rather than to have one large matrix to choose between several individual production levels of cows in one model, the model was run for one level of individual cow production at the time with nutrient requirements as belonging to the production level under study. This simplification has two advantages:

- the matrix is kept small;
- the model gives not one single optimum solution, but it shows how the solution changes when cows of different production levels are used.

Two farm designs were tried with cows producing from 0 to 16 l/animal/day.

- Case I: consisting of 1 ha sorghum cultivation and roadside grass. The daily DM availability from roughage was 6.5 and 6.0 kg respectively from these two sources besides a fixed amount of 3 kg of concentrate per farm. This case was tried with and without treatment of the sorghum stover.
- Case II: no access to roadside grass, 0.9 ha of sorghum cultivation and 0.1 ha of a legume tree (Leucaena). The total available DM from these two sources was 5.85 and 2.2 kg/day respectively. This case was tried with and without 3 kg of concentrate per farm/day.

The following assumptions were made for the design of the hypothetical farm, being realistic for the conditions of Gujarati farming under consideration and based on a BAIF survey, with prices at 1989 levels.

a. A landholding of one hectare per farmer is based on the BAIF survey of 1987 (unpublished).
b. Yields of sorghum grain and stover under rainfed condition are 2000 and 2400 kg DM/ha respectively.
c. Forage yields of cotton and Leucaena were assumed to be zero and 8000 kg DM/ha respectively.
d. DM intake of a cow of 350 kg bodyweight varies between 2.2 and 3.4% of bodyweight, increasing with the production from zero to 16 l milk/animal/day.
e. Maintenance requirements of cows for energy and protein were assumed to be 30 g TDN and 5 g CP/kg$^{0.75}$/day. The requirement of these nutrients for milk production was taken at 350 g TDN and 87 g CP/kg fat corrected milk (4% fat). (Euroconsult, 1989) which is based on NRC-standards.
f. Availability of homemade concentrate (18% CP and 65% TDN) was assumed at 3 kg/day/farm. This restriction may sound a bit odd, since increased income from increased milk production would allow increased concentrate purchases, but the case is quite common in the reasoning of cash strapped farming systems for which this model is meant.
g. Concentrations of TDN and CP in forages are shown in Table 1.
h. Roadside grass is freely available in Case I but one adult can only harvest a maximum of 6 kg grass DM in one hour, i.e. the total amount is limited by the amount of labour on the farm.
i. Farm gate price of milk, sorghum grain and cotton is 3, 1.5, and 6 INR/kg respectively.

j. Net income from sorghum and cotton is INR 1.26 and 3.5/kg (allowing for expenses incurred on seeds, fertilisers and pesticides but excluding labour, land rent, depreciation and interest).

Table 1 Energy and crude protein contents of forages (% of DM)

Forage	CP	TDN
Sorghum stover	4	50
Grass	11	55
Leucaena	24	60

RESULTS

Case I

The best combination was mixed farming, with a total milk production of 10.6 l/day, obtained from animals with a production level of 8 l/animal/day (Table 2). Beyond this level of production per cow, the cash crop (cotton) cultivation replaced grain production. This is because a higher production per animal makes it impossible to utilize the sorghum stover in the ration. If stover cannot be put to use through the production of milk then the income from grain alone is less then cotton. If stover can be used, then the combined value of grain and stover is higher when stover is only considered as animal feed and when its value such as for fuel in the household is ignored.

The analysis shows that the limiting factor for increased dairy production per farm and per cow is the availability of CP. This would suggest that research and extension should focus on provision of crude protein, by methods such as:

- additional concentrates or use of concentrate with a higher protein content,
- supplementation with protein rich forage,
- urea supplementation or treatment of the stover.

Two such alternatives were actually studied in case I. The first is urea treatment of the stover. Use of urea treated stover increased the number of animals that could be supported and also the total production per farm improved at all levels of individual cow production. Use of straw treatment had little effect on the total system production when animals of low individual production (< 2 l/animal/day) were used. The individual production that gave maximum income of this mixed farming was 10 l/day giving a total production of 14 l/day/system. Beyond 10 l/animal/day, cotton cultivation was selected in a progressive manner (Table 2). In that case either the energy content or the dry matter intake of the available feeds became the limiting factor for increased milk production per cow and the system.

The total income of the farm followed a trend similar to the individual animal production, and was highest at 10 l/animal/day on TS. It is also apparent from Table 2 that urea treatment of stover does not offer much advantage when the individual productivity of the animals is low, which agrees with the findings of Nell *et al.* (1986), Rai *et al.* (1988) and Kumar *et al.* (1993). At a production of 10 l/animal/day, the use of treated stover resulted in additional income of INR 10/farm/day, i.e. INR 49 versus INR 39 on untreated stover which can easily cover the cost of treatment.

Table 2 Optimum crop combinations, herd size and production at different individual cow productions with or without treatment of stover (Case I)

Individual production (l/day/cow)	Total production (l/day/system)		Herd size		Cotton* (ha)		Total income from milk and crops (INR/day/farm)	
	US	TS	US	TS	US	TS	US	TS
0.3	1.0	1.1	3.5	3.6	0	0	10.5	10.5
2.0	5.1	5.6	2.5	2.8	0	0	22.2	23.8
4.0	7.8	9.2	1.9	2.3	0	0	30.4	34.4
6.0	9.5	11.6	1.6	1.9	0	0	35.4	41.7
8.0	10.6	13.0	1.3	1.6	0	0	38.9	45.9
10.0	10.6	14.0	1.1	1.4	0.4	0	39.1	49.0
12.0	10.4	12.9	0.9	1.1	0.8	0.4	38.9	45.9
16.0	6.6	6.6	0.4	0.4	1.0	1.0	27.6	27.6

Note: * total area is 1 ha, i.e. 0 ha cotton implies 1 ha of sorghum, 0.4 ha cotton implies 0.6 ha sorghum

Case II

The number of animals in case II was lower than in case I, due to less available DM from Leucaena than from roadside grass. Without concentrate supplementation the maximum total milk production of the system was 5.4 l/farm, which increased to 10.7 l after supplementation with 3 kg of concentrates. The individual animal production was also higher on the supplemented as compared to the unsupplemented diet.

The limiting nutrients in case II are shown in Table 3. Without concentrate supplementation, CP was the limiting nutrient for all production levels while TDN became limiting for the production levels beyond 10 l/animal/day. With concentrate supplementation, TDN was the critical nutrient at low levels of milk production (< 6 l/animal/day) while CP became limiting at 8 l/animal/day. At high milk yields per animal, it becomes impossible to use high levels of stover in the cows diet, just as in case I, because of the low nutrient concentration of the stover. This means that the stover becomes without value (again ignoring its use as fuel, thatch etc.), and the income from the cotton cash crop alone becomes higher than from the grain crop alone when the stover cannot be fed.

The total farm income increased initially in case II (as in case I) with higher individual milk production both with or without supplement. It decreased again when the individual animal production became too high to incorporate the stover in the animal diet. The extra gain was small at lower production levels, and higher at the highest level of milk production where the increase was INR 14/day/farm which at current prices is more than the concentrate costs. It indicates that at low levels of milk/animal it is not wise to suggest supplementation, unless the supplement substantially increases milk production or improves lactation persistency, fertility etc.

The cost of treating stover is reported to be INR 180 per 1000 kg in this region (Rangnekar *et al.*, 1986). For treatment of 2400 kg of stover the total cost would be INR 430 as against the cultivation cost of Leucaena which is reported to be INR 2250 per hectare excluding irrigation costs and opportunity cost of the land (Relwani, 1983) as in our model. Thus for the case under

Table 3 Optimum crop combination, herd size and production at different individual cow productions with or without concentrates for case II (sorghum/cotton/*Leucaena*)

Cow type (l/day/cow)	Production (l/day/unit)		Herd size		Value (INR/unit)		Cash crop (ha)	
	C0	C3	C0	C3	C0	C3	C0	C3
0.3	0.5	0.8	1.8	2.6	8.0	8.8	0	0
2.0	2.6	4.0	1.3	2.0	14.3	18.2	0	0
4.0	4.0	6.5	1.0	1.6	18.3	25.7	0	0
6.0	4.9	8.2	0.8	1.4	20.9	30.9	0	0
8.0	5.4	9.4	0.7	1.2	22.8	34.6	0	0
10.0	5.4	10.2	0.5	1.0	22.6	36.8	0.22	0
12.0	4.2	10.7	0.3	0.9	19.4	38.1	0.59	0.1
14.0	0	8.0	0	0.5	7.9	31.1	1.0	0.8

Note: C0 = no concentrate; C3 = 3 kg concentrate/farm/day

Table 4 Limiting nutrients for production in the case of *Leucaena* but no grass.

Cow type	Production (l/animal/day)		Herd size		Surplus CP		Surplus TDN	
	C0	C3	C0	C3	C0	C3	C0	C3
0.3	0.5	0.8	1.8	2.6	0	0.26	0	0
2.0	2.6	4.0	1.3	2.0	0	0.15	0.16	0
4.0	4.0	6.5	1.0	1.6	0	0.08	0.42	0
6.0	4.9	8.2	0.8	1.4	0	0.03	0.56	0
8.0	5.4	9.4	0.7	1.2	0	0	0.7	0.03
10.0	5.4	10.2	0.5	1.0	0	0	0.30	0.21
12.0	4.2	10.68	0.3	0.9	0.09	0	0	0.18
16.0	0	8.0	0	0.5	0	0.27	0	0

Note: C0 = no concentrate; C3 = 3 kg concentrate/farm/day consideration, the cost of leucaena would be INR 225 per year as per 0.1 ha. These cultivation costs were based on prices in 1985 and assuming 25% increase it would work out to approximately INR 280. Thus, use of treated stovers seems to be more attractive than planting of *Leucaena* or any other similar crop when income is considered (INR 10.93 per day, i.e. INR 3989 per year). However it may be added that under dry farming conditions the forage would be available for a period of 8 months and very little production of roadside grass can be obtained during the summer months.

The use of such models can be helpful to understand the systems. The models however need to be refined, and should include refinements of the models, such as the use of integer planning, effect of herd composition and season effects. The inclusion of season effects by using multiperiod LP is shown in this workshop by Vijayalakshmi *et al.* (1993).

CONCLUSIONS

The quality of (un)treated stovers with or without supplements are insufficient to provide the nutrients for the animal beyond 10 l productivity (Tables 2 and 3). The model then suggests that use of cotton should replace the combination sorghum and livestock, though total income will decline. This clearly illustrates that livestock production cannot be seen in isolation of the cropping system. Integration of two sub-systems may require that the production levels of individual sub-systems may have to be adjusted to reach maximum total system productivity. Use of urea treated stover does not appear to be economical when fed to either low or very high producing animals. Mixed farming systems are potentially more remunerative than cotton or sorghum alone. They can provide additional labour opportunity, provided the individual animal productivity is adjusted to nutrient availability. The simple model of this paper is far from perfect, but it shows that optimum cropping patterns are affected by the type of animals or additional feeds available.

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FEEDING STRATEGIES DURING NATURAL CALAMITIES

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SUMMARY

Livestock production is affected by natural calamities that cause lack of water and feeds. The strategies for emergency feeding depends on whether animals have to be saved from starvation only or whether their production of milk etc. has to be maintained. The difficulty to slaughter animals in India, and the size of the nation, where floods and droughts can occur simultaneously, presents special problems of transport of feed. Some preliminary calculations about alternative strategies and their costs are explained. If transportation of feed (i.e. nutrients) is to be considered, the bulkiness of the feeds is a serious constraint by increasing the cost of transport. The use of high quality (i.e. concentrated) feeds, or the densification of straws are options to reduce the bulk to be transported. Some densification methods are briefly discussed here. If transportation of feeds is not feasible, nutrients can be diverted from the feeding of a relatively smaller number of animals that produce milk or liveweight gain, to the feeding of a larger number of animals at (sub)maintenance levels of production. In this case the survival of animals becomes the most essential form of animal production. The differential effects of these strategies on farmers' income (short and long term) and incurred risks are discussed. Finally some attention is given to important aspects like weather forecasting to assess risks and to facilitate precautions, improved use of conventional feeds and water requirements of the animals.

INTRODUCTION

The average individual milk production for cows and buffaloes in India is very low i.e. 157 kg and 504 kg respectively (NCA, 1976; Dairy India, 1987). This is mainly due to insufficient feed quality and quantity. Cereal straws form the major source of feed for ruminants in India but estimates based on energy requirements indicate that there is not enough straw produced annually to feed all the ruminants in India. Even if the quantity of straw would be sufficient, the quality can restrict the use of straw, depending on the purpose of production (Zemmelink, 1986).

The shortage of animal feed is further aggravated by frequent calamities that can be classified on the basis of their effect on feed resources, their duration, extent, seasonality, certainty of occurence and relative shortages of protein or energy. Natural

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calamities that directly affect the feed availability include: floods, droughts, cyclones, land slides, hailstorms. Political instability such as wars, fires and blockades also indirectly affect the feed availability. Such calamities increase the gap between the demand and supply of feed. The feed supply of Gujarat, Rajasthan, Karnataka and Maharashtra was badly affected in the serious drought of 1984-1987.

In fact, it has been estimated that 43% of the total livestock in India are perpetually affected by drought. Also, floods in the Northern region of the country take the lives of humans and livestock and it is reported that 10000 livestock and 1400 human lives were lost every year from 1953 - 1986 (Sastry, 1989). The government regularly spends large amounts of money for the protection of human lives and maintenance of livestock during these drought and flood periods. Milk procurement under the Operation Flood program was reduced by 9% per day in 1987 in some states as compared to 1988, only partly caused by organizational problems.

The feeding of animals during scarcity is discussed in many publications, e.g.: Champion (1971), Ranjhan and Khera (1981), Saville (1981), Leng (1986), Leng and Preston (1987), Sharma (1987), Kunju (1987), Rangnekar (1989), Cronjé (1990) and Fordyce *et al.* (1990). Most of these papers however merely list the feeds to be used without elaborating the strategies to be followed. Moreover, much of this literature elaborates supplementation of animals in situations where feed quality is low, but where sufficient dry fodder is available. This situation occurs in ranching conditions where the "animals are starving in a sea of plenty" (Altona, 1966), i.e. where the quality of the basal roughage does not permit optimum rumen functioning. In that case use can be made of catalytic effects of certain supplements on utilization of low quality fodder, and on animal survival and production (Preston and Leng, 1987; Cronjé, 1990; Prasad *et al.*, 1993). However, Fordyce *et al.* (1990) elaborate feeding strategies and their applications for animals in different stages of pregnancy, age and body condition, to maximize survival rates and subsequently to minimize a reduction of reproductive performance after scarcity.

This paper discussses economic aspects of drought feeding strategies such as:
- adjustment of feeding strategies;
- purchasing the feed from areas with feed surpluses and
- reduction of transport costs.

The examples are fictitious and they have been kept very simple, e.g. no distinction has even been made between compensatory production of dairy or beef (Allden, 1970; O'Donovan, 1984; Robinson, 1990). Also, the assumptions on herd compositions or mortality can easily be challenged, but the paper is meant only to serve as an outline of work that needs to be developed and refined subsequently.

SCARCITY FEEDING: OBJECTIVES AND STRATEGIES

The type of feed shortage determines the strategies for emergency feeding. Some nutrient shortages concern a lack of feed quality (energy and/or protein), others concern an absolute lack of quantity. Feeding strategies during droughts can have one or more of the following objectives:
- to feed animals for maintenance at a minimum body weight, leading to a strategy that ensures survival of animals from the available feed);
- to feed animals to maintain weight above the critical or minimum bodyweight including allowance for weight gain in growing animals. In a long drought this would mean that less animals would survive as the available feed would be used quicker;
- to preferentially feed productive stock, such as pregnant and lactating cows. This is called strategic feeding, it would again mean less feed for other animals).

Critical body weight is the body weight below which mortality rate rises rapidly. Definite threshold values are difficult to give and depend on duration and type of underfeeding, as well as on the loss of production that is considered acceptable. If the animal has good fat reserves it will use these as a source of energy during weight loss. Animal deaths in drought are mainly due to exhaustion of body fat reserves. The tissues of animals dying from starvation for example, contain less than one percent crude fat (Champion, 1971). As an example, the critical body weight is approximately 35 kg (at a condition score of 1.5) for Peppin type Merino sheep which is a relatively small body size in Australia. At maximum condition score 5, their weight would be around 65 kg. If the same sheep was to be maintained at 40 kg weight, 11% more feed would be required each day. For Indian farming systems these values are quite different, but no detailed information is available.

The survival or critical body weight varies with species, strain, breed and age of the animal. It has been reported that cattle will die if weight loss is > 20% of body weight, while sheep and camels can tolerate weight loss up to 30% of the body weight (Leng and Preston, 1987). Cronjé (1990) gives critical bodyweight losses of 30 - 40% in cattle and sheep. Obviously, the weight loss that can be tolerated depends on the original weight and condition of the animals, as well as on the physiological status of the animals: i.e. young stock tolerates less weight loss compared to mature animals (Cronjé, 1990). An adult animal in good condition can also lose more weight than the same animal in poor condition. Part of the weight loss may be caused by lower gut fill. A knowledge of critical weight losses for different species is required to optimize feed resource allocation during emergency, but these are not commonly available in India. It would also be useful to use or develop condition scoring techniques to estimate how much weight individual animals are able to lose.

The effects of temporary weightloss can be recovered by compensatory gain (O'Donovan, 1984) especially in growing animals. Farmers all over the world apply this principle especially in beef animals where they let the animals lose weight in time of scarcity, in order to gain weight in times of abundant feed supply. For milk production, the effects of periodic undernutrition on general health and fertility reproduction are however more likely to be of a long term nature. Lactation curves are unlikely to recover and calving rates and conceptions may be lowered (Allden, 1970; Robinson, 1990)

STRATEGIES BASED ON REALLOCATION OF A GIVEN AMOUNT OF FEED IN THE HERD

The first major option to overcome a feed shortage is to adjust the animal production to the feed availability. Hypothetical and simplified calculations on the economics of different feeding stategies are given below to illustrate this option. The calculations have been done for a large herd with a given composition. Choices for smallholder herds will work out differently and they need special study since e.g. 10% mortality in a large herd works out different than 10% mortality in herd with one or two cows. Details on an assumed fictitious herd structure and production are given in Table 1. The mortality is assumed to be entirely caused totally by starvation because no pasture was available and no feed was given to these animals. Three strategies to adjust feeding patterns and reduce mortality rates are considered:

a) diversion of nutrients from milk producing animals to all other animals of the entire herd;
b) diversion of nutrients from growing animals and bullocks to save other livestock;
c) diversion of nutrients from both milk producing and growing animals to the starving animals.

Ad a: Milk production is reduced and the nutrients are diverted to feed the undernourished animals as per their requirements for maintenance. It is estimated that the farmer has to divert the nutrients of 230 litres milk/day to save all the animals, e.g. about 30 INR/animal/day. This would **reduce total milk production** from 290 to 60 litres, greatly reducing farmers income, but securing the survival of more animals.

Ad b: This is the diversion of nutrients from growing animals and bullocks to save other livestock. If the growing animals were fed sufficient nutrients to gain 400 g/day and bullocks and old cows were offered 80% of their requirement, 10 out of the 29 animals at risk can be saved. In this strategy **milk production is not reduced**.

Ad c: If a farmer does not want to lose so many animals and if he/she cannot afford to cut milk production as drastically as in option A, the strategies can be combined. In this case some nutrients would be diverted from milking as well as from growing animals, thereby **saving almost all animals** at the cost of 120 kg milk/day (Table 2).

The strategies differ in many respects and their applicability depends on the conditions in the farming system under study. A reduction of milk yield results in a decreased daily income, which may be difficult to accept for farmers who do not have sufficient other sources of income or cash reserves. The feeding of animals below their requirements (strategy B) is risky because

Table 1 Assumed herd structure and mortality rates.

Type of animal	Body weight (kg)	No. of animals	Milk or gain per day	Mortality (%)	No. of animals dying of starvation
High prod.	400	20	8 kg milk	0	-
Medium prod.	400	20	5 kg milk	0	-
Low prod.	400	10	3 kg milk	0	-
Old cows	400	10	-	100	10
Ad.preg.	400	15	-	35	5
Bullock	500	10	-	40	4
2 - 3 yrs	250	9	600 g/day	11	1
1 - 2 yrs	150	8	600 g/day	12	1
0 - 1 yr	75	8	500 g/day	100	8
TOTAL		110	290 kg milk + 9 kg growth/day		29

Note The nutrient requirements of the animals have been calculated as per NRC (1989). The other values are assumptions based on field experience

Table 2 Mortality rate of animals under different feeding adjustments (based on field estimates)

	Mortality of animals			
	Expected mortality without intervention	Strategy		
		A	B	C
Category of animal				
Pregnant cows	5	0	0	0
Old cows	10	0	5	2
250 kg heifers	1	0	1	0
150 kg heifers	1	0	2	0
75 kg calf	8	0	6	1
Bullock	4	0	5	1
Total dying	29	0	19	4
Saved animals	0	29	10	25
Milkprod. (kg/day/herd)	290	60	290	170
Loss of LWG (kg/day/herd)	5.2	0	5.6	3.9
Number of animals at 80% of maint.	0	0	10	17
Cost of dying animals (*1,000 INR/herd)	140	0	75	18.5

Assumptions:
0. shortage of feed is the only cause of mortality. Dying animals are not fed at all.
1. cost of milk INR 4 per kg
2. cost of pregnant cow INR 8000
3. cost of old cow INR 6000
4. cost of heifer (250 kg) INR 5000
5. cost of heifer (150 kg) INR 3000
6. female calf (75 kg) INR 1500
7. bullock INR 5000

more animals may die eventually if the calamity continues for a longer time. The choice of strategy is obviously affected by the nature of feed shortage, whether it is regular and predictable or irregular and unpredictable. Both situations are common in the wide variety of Indian farming systems. Strategy B also results in underfed cattle that are less valuable after the calamity. The extra value or costs of these animals is, however, difficult to assess partly because of compensatory gain or lower fertility rates, especially of the younger animals. Also, the value of animal survival is much higher for predominantly Hindu society of India than in many other countries of the world. The relative need to possess an animal that can pull the plough at the next rainy season further complicates the valuation of mere survival as a form of animal production.

STRAREGIES BASED ON THE PURCHASE OF FEED

The second major option to save animals is to purchase feeds from surplus regions. High transport costs are then involved, particularly in a large country like India where extreme droughts and rains can occur simultaneously and where slaughter of animals is generally considered taboo on religious grounds. It is essential that the cost of feeds are considered on the basis of their nutritive value and that transport cost be included.

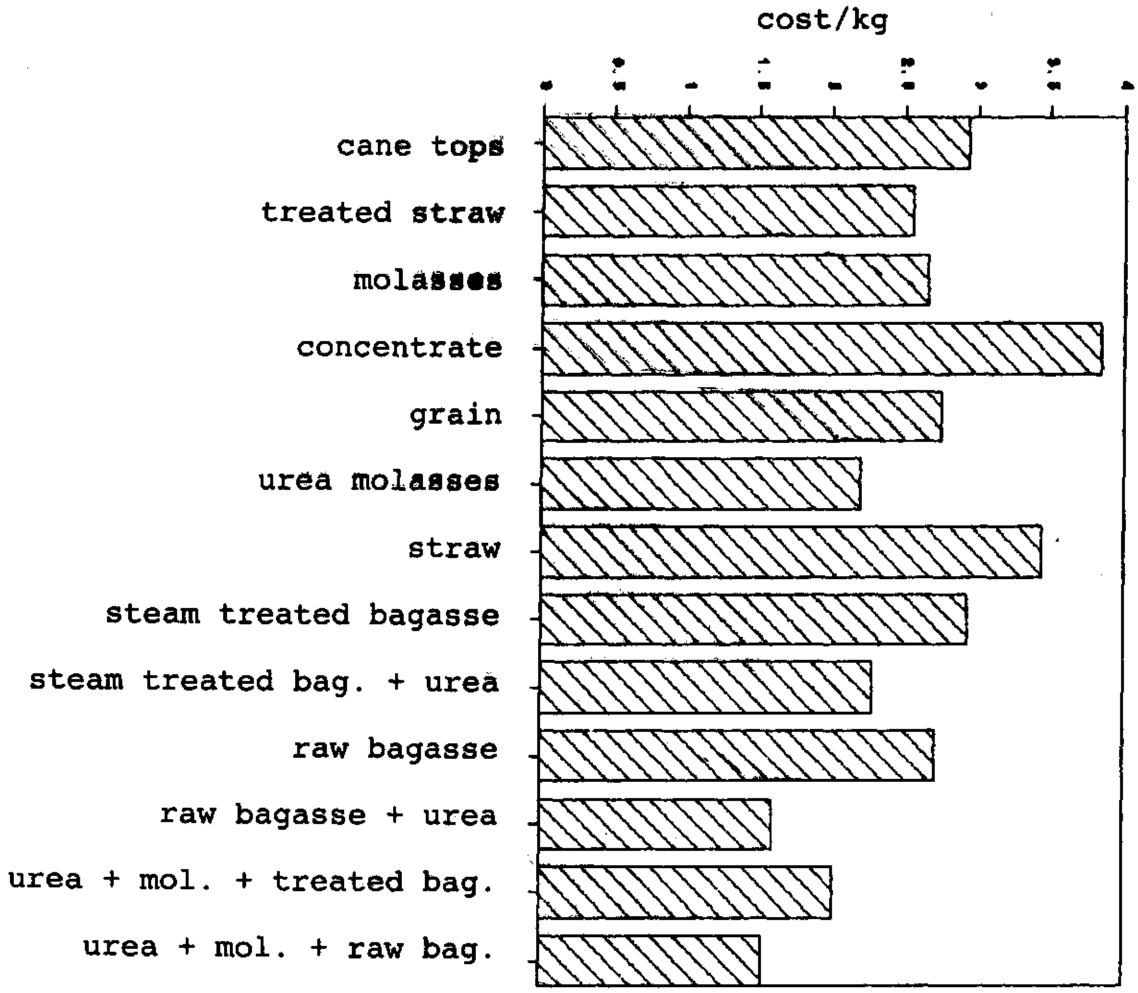
On this basis highly nutritive feeds like grain may prove to be the most economical if feed is transported over large distances even more so if costs are expressed in terms of nutritive value, e.g. TDN or CP. The calculation of Table 3 shows that at larger distances, i.e. beyond 200 km. the cheaper transport of concentrates favours the cost of nutrients from grains over dry grass. Note that this applies to the cost of grass that is not densified, i.e. only loosely studied.

Table 3 Cost of grass and grain at different distance

Particulars	Unit	Grain	Dry grass (not densified)
Cost	(INR/1000 kg)	2000	1200
Quantity/truck	(kg/truck)	10000	2000
Cost of transport	(INR/km/truck)	10	10
Cost of feed for 100-400 km.			
	(INR/1000 kg/100 km)	2100	1700
	(INR/1000 kg/200 km)	2200	2200
	(INR/1000 kg/300 km)	2300	2700
	(INR/1000 kg/400 km)	2400	3200

The option of grain feeding however has limited value because good quality feeds are already scarce under normal circumstances. Market prices do not always reflect actual availability and grains are not likely to be diverted from human consumption if the calamity is of such a scale that it also affects human nutrition. Therefore, feeds available for purchase include agro-industrial byproducts such as bagasse, grainmilling byproducts and molasses or grasses and straws from the fields. The daily requirement of CP and TDN to maintain the 29 animals which would die without intervention in the example of Table 2 would be 15 kg and 72 kg per day respectively. The milk production of the cows will be maintained in that case.

Figure 1 Cost of nutrients to save the animals (expressed in INR/kg)



Different feeds were compared to supply the required nutrients for the herd, and their chemical composition of feed was taken from NRC (1988). Transport charges are not included in the prices of these simplified calculations, but in reality transport costs can be substantial and need to be considered. The cost of the nutrients to save the animals with different rations is presented in Figure 1. The cost of nutrients from bagasse was lowest and the cost of nutrients from concentrate was highest (transport excluded). The cost to save the animals by diverting nutrients from milk production to the animals at risk was 230 kg milk per excluded). The cost to save the animals by diverting nutrients from milk production to the animals at risk was 230 kg milk per day, i.e. INR 920, but by purchasing the feed the cost is only INR 250 per day on concentrate feed and INR 150 per day on unconventional feeds like bagasse. This situation changes considerably if feed is not available nearby and transport costs are incurred (Table 3). Experiences in the Gujarat drought were that the price of grass or straw doubled, due to transport costs and because the feed supply becomes limited. Hereunder some attention is given to the options to reduce transport cost for the bulky feeds by densification.

REDUCTION OF TRANSPORT COSTS

Grasses from forest areas or crop residues from regions with surpluses are commonly transported to feed animals during droughts. The possibility of transport depends on the nature of the calamity as discussed in the introduction. Transportation of feed is only an option if the drought is regional. It has little or no value if infrastructure is highly damaged (floods) or if the calamity is of a much larger scale (severe droughts that occur throughout most of India). In the case of the 1984/1987 drought in Gujarat, it was observed that transport costs were at times higher than the costs of the feed itself.

One way to reduce transport costs is to compress or to densify the bulky feeds. Jadai *et al.* (1990) reported that there was 2.25 - 2.70 times increase in bulk density of straw based complete feed. Densities can be increased from 65 - 75 kg/m^3 to 100 - 110 kg/m^3 by baling or even 300 - 500 kg/m^3 by briquetting (Bruhn *et al.*, 1975), which seems very high however. The costs of baling grass by hand and bullock driven presses (pada press) is given in Table 4. The quantity of feed which can be transported in each truck is more than doubled after baling. The calculations of Table 4 show that when transport distance exceeds 50 km the costs of baling are recovered by reduced transport costs in case of pada press with our (over)simplified calculations. The cost for hand pressing is recovered when transport distance exceeds 150 km. Extra benefits like reduced storage costs, less spoilage

Table 4 Economics of baling

Particulars	Unit	Lose grass	Hand press	Pada press
Cost of baling	INR per 1000 kg	-	200	125
Weight of grass	kg per bale	-	50	100
Quantity of grass/truck	1000 kg	2000	3000	5000
Transport and baling cost	INR per 1000 kg			
* over a 10 km distance		50	230	145
* over a 50 km distance		250	367	225
* over a 100 km distance		500	533	375
* over a 150 km distance		750	700	425
* over a 200 km distance		1000	867	525
* over a 300 km distance		1500	1200	725

and consequently increased quality of the feed are likely to occur, but difficult to quantify at this stage. It also depends on the type of straw and the method of densification.

OTHER STRATEGIES TO OVERCOME FEED SCARCITY

Reduction of wastage by chaffing

If straw is insufficiently available for feeding of all animals, the reduction of wastage might be an option. It is reported by Shukla *et al.* (1988) that 15 - 20% of the the straw offered is refused when it is fed unchaffed. Therefore chaffing, may be worthwile, even though it reduces the selection by the animals for the most digestible parts like leaves (see the discussion of selective consumption by Ranjhan, 1993). In Haryana and Punjab states chaffing is common on farms, but it is not widely practised in other areas, probably for nutritional reasons as elaborated by De Wit *et al.* (1993).

Straw treatment

Treatment of straws would not be expected to contribute to the nutrient supply during emergency feeding, if the major advantage of treatment is the increased intake of the straw in order to save relative expensive supplement (Schiere and Nell, 1993). However, the transport of urea or ammonia, and treatment might be cheaper than the purchase and transport of additional concentrate or roughage. In that case the intake of treated straw is to be limited to what is required for the desired (sub-) maintenance level of nutrient supply.

Feed storage

The surplus feed from good years can be stored for use during calamities or even during the lean seasons of the year when prices of fodder increase sharply. Making of hay or silage is unlikely to be useful in generalized rural conditions but a study is required to specify the (dis)advantages per farming system.

Complete feeds

Complete feeds imply a system of feeding all ingredients including roughages, processed and mixed uniformly, to be made available *at libitum* to the animals (Sharma and Singhal, 1986). Complete feeds can be produced in mash and pelleted form when this product is fed as sole source of nutrients. Pelleting of complete feeds increases voluntary intake by 3-30% and processing cost by 57-130% depending upon the type, percentage and original cost of roughages in the ration (Reddy, 1986). If baling of fibrous feeds is practiced, it can be useful to produce complete feeds for use during droughts, i.e. to add some concentrate ingredients. Biologically, the use of complete feeds with an appropriate balance of roughage and concentrates may lead to better utilization of locally available crop residues, agricultural-byproducts and waste. Complete diets for livestock could benefit rural farmers during periods of feed shortage if the feed and transport costs can be kept low. Otherwise city farmers will be more likely to buy them. Not many studies on economics of this system are known, but the BAIF Development Research Foundation (Rangnekar *et al.*, 1986), Andhra Pradesh Agricultural University (Reddy, 1986), National Dairy Research Institute - Karnal (Sharma and Singhal (1986) and Hisar Agricultural University (Rathee and Lohan, 1986) are engaged in developing complete feeds on locally available byproducts like bagasse, mixed with tree leaves and other unconventional byproducts. However, the composition of the complete feed needs to be adjusted to the production level of the animals, which is a complication for processing and distribution of this type of feed.

Weather forecasting

The choice of the best strategy depends on the type and duration of the calamity. The weather forecasting and extension system should be well established which will help the farmers to prepare for the calamities in advance. For floods this might be a reasonable possibility. For droughts the decisions on preferred strategies would be easier if the duration of the drought was known. This is never the case, but historical records of climate and duration of droughts in different areas of India might enable development of predictive models to give best estimates of likely duration of droughts.

Fodder trees

Tree planting has been started on a large scale in India. Trees have the advantage that they produce fodder less affected by various calamities. Tree growing could also be done for other purposes like the production of timber (Hegdé, 1992; Devendra, 1990).

Small versus large animals

Farmers in drought prone areas keep animals to supplement their income from crop production which is more directly affected by drought. A failed grain harvest can to some extent be compensated by using the stores for animal feed. In comparison to large animals, small ruminants like goats and sheep have some advantages:

- rapid recovery of the population after calamities are over because of their higher prolificacy;
- small ruminants are not affected by the religious taboo on slaughter;
- they are typically multipurpose animals combining the production of wool, mutton, milk and/or hides;

- their feed requirements per animal are lower, facilitating the possibility of diversified feeding strategies and thereby the survival of part of the herd.

Water requirement of livestock

An essential requirement of a living organism is "water". The water availability during a drought is essential as water helps to regulate the body temperature, for transport of nutrients, etc. The water requirement is related to factors like heat load, production traits and DMI. The water requirement of an animal is in the range of 2.5 to 4.5 l/kg DMI. A more detailed review of water requirements is needed, but Murphy *et al.* (1983) give the following equation for lactating cows in early lactation in Western conditions mainly:

Water intake (kg/day) = 15.99 + [(1.58 ± 0.271) * DMI] + [(0.9 ± 0.157) * kg milk/day] + [(0.05 ± 0.023) * sodium intake in g/day] + [(1.2 ± 0.106) * minimum daily temperature in °C]

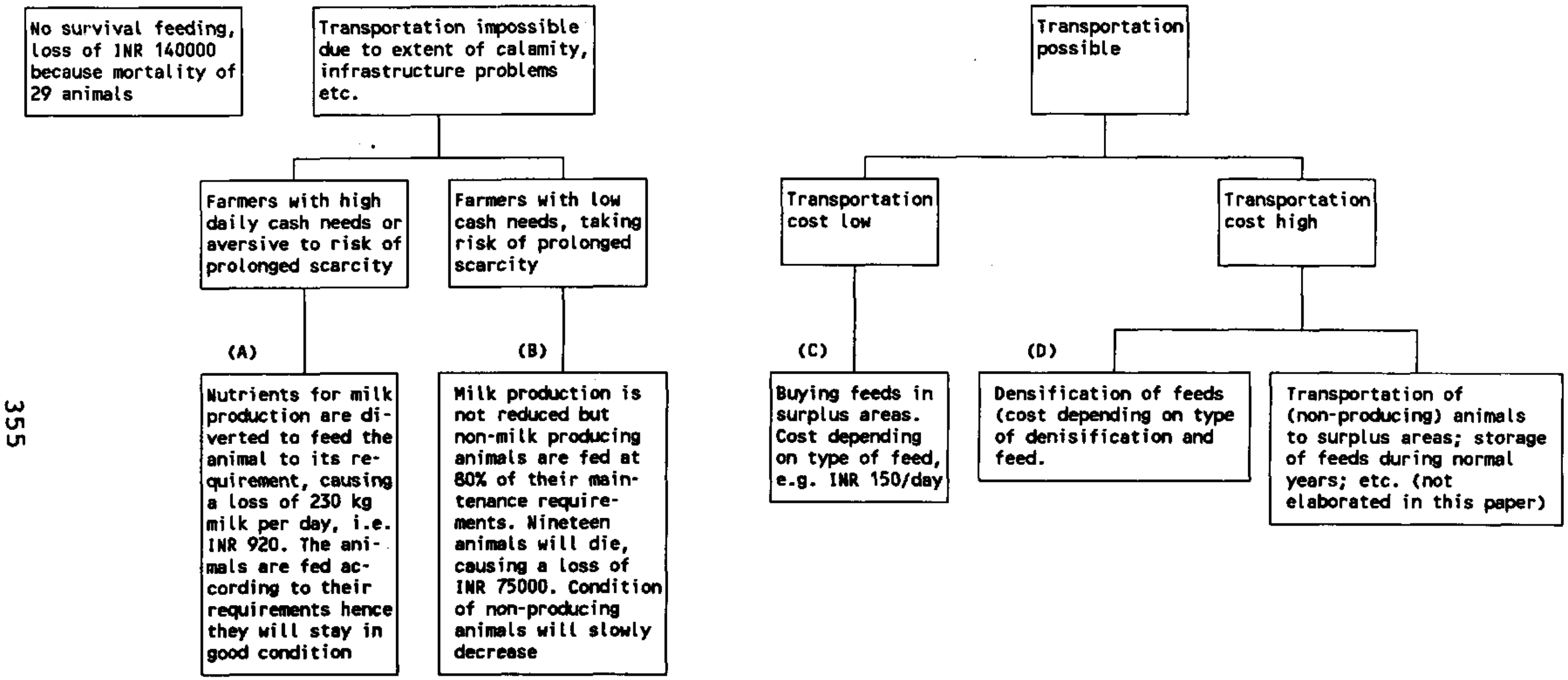
The ratio of Water Intake:DMI will also rise if feed intake is restricted. Therefore, it may be better to express water requirement as a percentage of body weight.

Required frequency of watering is not well studied and depends on the type of animal. Extending watering frequencies to 2-3 days have proven to be practical during drought periods for large ruminants when water is scarce. This has the advantage of reducing overall feed and water consumption with possible improved nutritional benefits in terms of increased feed digestibility (Leng, 1986). The inceased feed digestibility is primarily due to increased retention time of digesta in rumen. Body reserves were unaffected due to extending water up to 3 days as compared to daily offered (Leng, 1986). The effects of restricted water intake include reduced urine output and reduced feed intake. If the water deprivation is severe, dehydration will occur, combined with protein catabolism and finally a failure of the renal function.

A DECISION TREE ON FEEDING STRATEGIES

Some of the scarcity feeding strategies discussed in this paper, are again, systematically, shown in diagram 1 along the lines of a so-called decision tree (Dohoo, 1984; Chamberlain and Esslemont, 1990).

Diagram 1 : A simple decision tree for scarcity feeding



CONCLUSIONS

Many authors discuss feeds to be used during droughts, but only few discuss feeding strategies according to type of calamity. Such strategies can vary from the feeding of many animals at (sub)maintenance levels to the feeding of a few animals for production, from supplementation to maintain production or accepting lower production with lower cost of supplementation. The suitability and economics of strategies for feeding animals during droughts differs between type and duration of feed scarcity, resource condition and objective of the farmers, as well as between locations and type of animals.

Cost of nutrients and transport of grains is often cheaper than transport of dry fodder, but since grains are food for humans they can not extensively be used for animal feeding. Transport of grass or straws is expensive but it may be the only way to feed the animals during calamities. Densification can reduce transport cost but is only economical beyond a certain distance, which is around 50 km in our hypothetical example.

A number of other approaches is possible and include reduced wastage, treatment, storage. The merits of each of these can only be discussed while considering the type of emergency and the appropriate strategy.

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FEEDING OF UREA TREATED STRAW IN DAIRY CATTLE

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ABSTRACT

Twelve cross-bred male calves in the age group of 7-8 months were divided into two uniform groups. Animals in group I were fed on urea treated straw (UTS) ad libitum *(4 kg urea dissolved in 50 kg water spread over 100 kg rice straw and stored for 3 weeks) and the animals in group II were fed on untreated straw ad libitum. Each animal was also provided with 700 g commercial type concentrate and 3 kg green para grass per day. Feeding of this ration was continued for 177 days. The total and straw dry matter intake (kg/100 kg body weight) was 2.77 and 1.51 for group I and 2.57 and 1.14 kg in group II. The feeding of UTS increased the straw DMI by 32% and live weight gain by 41%.*

During the experiment, UTS was also supplied by the station, free of charge, to some landless farmers to feed their cross-bred calves in age-group 9 - 18 months. Those farmers discontinued the feeding of UTS after 2 months because of availability of green grass for grazing, even though UTS was supplied by the Institute free of cost.

On the same basis 3 milking cows producing 4.5 to 8 kg milk/day were also fed UTS in an on-farm trial. Farmers reported an increase of 0.5 - 0.6 kg milk/animal/day. One of the farmers reduced concentrate level from 4 to 3 kg by ad libitum *feeding of the cows on UTS and little amount of kitchen waste, maintaining 7 kg of milk.*

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SESSION FIVE

VARIABILITY OF STRAW QUALITY AND QUANTITY AS CAUSED BY CULTURAL PRACTICES AND PLANT GENETICS

VARIABILITY OF STRAW QUALITY AND QUANTITY AS CAUSED BY CULTURAL PRACTICES AND PLANT GENETICS

Straws in general have a low nutritive value, but considerable difference exists between varieties and species of straws. Such differences may be caused by genetic effects as well as by cultural practices.

Quality can be expressed in terms of digestibility, rate of degradation, or intake. Traditional varieties such as Basmathi rice are generally assumed (though not proven) to produce better straw than other rice varieties. Coarse straws of millets and sorghum are generally better than the slender straws of wheat, rice etc. as discussed in the previous sessions. Quality can also differ considerably between plant parts, with leaves often - though not always - being better than stems.

Quantity of straw produced also differs considerably between varieties, species and management conditions/cultural practices. Modern cereal varieties have relatively higher harvest index (grain as a proportion of total above ground biomass) than traditional varieties, but the total straw biomass per area unit of modern varieties may increase in some cases due to higher total biomass yields. There is evidence that increases in straw quantity and quality need not affect grain yield negatively.

Plant breeders in the past have given most attention to an increase of the total grain yield as explained for fingermillet in the paper of Seetharam et al. *As fingermillet breeders they found that certain high grain yielding varieties were not accepted because of the straw quality or quantity. That paper discusses the genetic variation found in some fingermillets and concludes that breeding for straw with a good quality is likely to be possible without affecting grain and forage yield negatively.*

Possibilities to improve straw quality and/or quantity are subsequently discussed for grain sorghum (Badve et al.*) for fingermillet (Subba Rao* et al.*) and for rice and wheat (Mahendra Singh* et al.*; Soebarinoto* et al.*). The latter paper also discusses experiences from Indonesia and issues of research methodology.*

Some preliminary conclusions of these papers are that
- *variability due to genotype exists in rice, fingermillet and sorghum;*
- *leaves are more digestible than stems in sorghum and fingermillet, but the differences are not great;*
- *growth circumstances and fertilization may affect quality, but have a more pronounced effect on quantity of straw produced.*

The relevance of breeding or managing the grain crop for more and/or better straw depends very much on the prevailing farming system. Availability of other good quality feeds as well as the type and level of animal productivity affect these choices as *elaborated in the paper of De Wit* et al. *The magnitude and the repeatability of quality and quantity differences, as well as the requirements of the various farming systems will decide the usefulness of future work in this field.*

RECOMMENDATIONS ON STUDIES OF VARIABILITY IN QUALITY OF STRAW FROM FINGERMILLET AND SORGHUM

Genetic and environmental management effects

Work on repeatability of OMD of straws with regard to correlation across years of growth and comparison of variation within year of growth should be continued for at least two more years with a selection of the varieties studied so far. Growth conditions should be recorded for the various years (rainfall, light, intensity, temperature) in cooperation with plant physiologists, besides traits as leaf context, plant height and days to grain maturity.

Genotype * location effects should be studied with a number of varieties grown on three locations, that differ in average temperature, precipitation, light intensity and soil quality. Other conditions should be described e.g. fertility, sowing time, growth duration.

Experiments (preferably under controlled conditions) should lead to a better understanding of effects of environmental factors on plant physiology and straw quality. Parameters to be studied are:
- leafiness;
- translocation of solubles from stem to grain;
- digestibility;
- hemicellulose/cellulose ratio;
- lignification of cell walls as affected by light intensity, temperature, rainfall and fertilization.

Contrasts between varieties among years or locations may vary widely. The environment of growth should be defined in terms of which varieties show the largest contrast. Further selection work could be carried out with varieties grown in such an environment. This will only work, when genotype * environment interactions are of low importance.

Studies of the genetic component in variability of straw quality by comparison of parental lines and their offspring are to be done.

Screen the existing population of germ plasm for straw quality (low priority).

Research should focus on trying to find simple (compositional, morphological) parameters to describe straw quality.

Since straw quality, grain yield and fodder yield are not always negatively correlated, and since harvest index and straw quality and fodder yield tend to be negatively correlated, selection aimed at fodder mass and fodder quality should take biomass per se and not harvest index as an important criteria. Relations as given above should be confirmed with larger groups of varieties.

Grain yield should remain the first priority of breeding, though the priority on grain may be less for rainfed areas.

Implications for animal nutrition

Intake of straws by ruminants should be studied with high priority. These intake data should be correlated with *in vitro* data and relevant compositional and morphological parameters.

Integration of *in vivo* intake and digestibility data into estimation of animal performance and economic modeling should provide tools to breeders and extensionists in developing strategies with regard to selection of varieties and target groups, respectively.

Management effects

There is a need to study
- the effect of fertilization of N and P;
- the techniques to decrease post harvest losses.

General

There is a need to
- study the role of green fingermillet or sorghum as a forage crop in temperate or tropical areas, as well as to
- organize (inter)national meetings on the subject of variability in straw quality.

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GENETIC PARAMETERS AND RELATION OF MORPHOLOGICAL CHARACTERISTICS ASSOCIATED WITH FODDER YIELD AND QUALITY IN FINGERMILLET (*Eleusine coracana* Gaertn.)

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SUMMARY

The present day improved cultivars of fingermillet are often inferior to local species as far as fodder yield and quality is concerned. This is because the breeders, while improving grain production, were unaware of simultaneous changes in nutritional quality and quantity of straw. The existence of variability in many parameters determining fodder quality of straw suggests that varietal differences exist for both fodder yield and quality. The immediate need is to screen available germplasm for nutritional quality and quantity parameters of straw to obtain a better insight into the existing variability and the likely extent of genetic advance that could be made. This variability presumably could be exploited to improve the fodder characteristics of the future varieties through well defined breeding programs.

INTRODUCTION

Fingermillet is an important coarse cereal grown for both grain and fodder, in India and elsewhere (Gowda *et al.*, 1988, Sampath *et al.*, 1989, Purseglove, 1972; Metuchen, 1967). Its utility as a source of dry fodder for ruminants is quite significant. In drought years it is common for farmers to accept lower grain yields rather than to lose fodder when there is acute shortage of crop residues. The common emphasis in crop improvement programs is however to increase grain productivity and quality; straw quantity and quality has been a secondary consideration. This was caused by shortage of food grains in the country, and a monodisciplinary focus on grain only. After having attained self-sufficiency in cereal grain production, the plant breeders are increasingly aware of the need to upgrade the quality and quantity of crop residues, since cereal straws form a major source of feed for animals in India. Gowda *et al.* (1988) pointed out that grain and fodder should be given equal importance in coarse cereal improvement programs.

Kelley *et al.* (1991) discussed plant breeding policies and their implication for forage yield whereas De Wit *et al.* (1993) analysed the relative importance of straw quality and quantity for different farming systems. The nutritive value of cereal straw is influenced by many factors : cultivar, management and

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environment (Doyle *et al.*, 1987; Reed *et al.*, 1988; Pearce *et al.*, 1988). Recently we have started looking at the value of crop residues of fingermillet to establish the variability in elite material in terms of fodder quality and quantity parameters. The available preliminary data have been used to work out the basic genetic parameters of the fodder quality parameters. This could form the basis for possible future manipulations of these characters. In this paper, the results obtained at the Project Coordinating Unit, All India Coordinated Small Millets Improvement Project, G.K.V.K. centre, Bangalore, in collaboration with the Animal Nutrition Department of National Dairy Research Institute, Bangalore, are discussed.

Comparative feed value of local (old) and improved (new) cultivars under different fertility levels

Breeders have aimed to increase grain production. Most of the yield increase has come through improvement in harvest index (HI) in the new varieties released where harvest index is defined as the percentage grain in the total above ground biomass. Three cultivars Hullubele (land race), PR 202 (a pure line selection from land race) and Indaf 8 (a recently bred high yielding variety) were compared for grain yield, fodder yield, harvest index (HI), organic matter content (OM), cell wall content (NDF), organic matter digestibility (OMD), and digestible cell wall content (DNDF) of the straw at three levels of fertility management. The experiment was laid out in factorial RCBD. The ANOVA indicated highly significant varietal differences for all characters studied except for NDF (Table 1). The fertility levels influenced significantly all the characters except HI and OM. The interaction due to variety and fertility level was significant for both grain and fodder yield, HI as well as NDFD. This suggests that the improvement in the nutritional value of the straw could be achieved simultaneously with increased grain and fodder production.

Table 1 Analysis of variance for seven characters in fingermillet as affected by variety and fertilizer

Source	df	Mean squares						
		Grain yield	Fodder yield	Harvest index	Organic matter	NDF	OMD	NDFD
Replications	2	0.095	0.608	0.000	1.057	5.281	0.271	0.762
Varieties	2	4.199**	9.865**	0.029**	10.824**	1.842	12.768**	14.737**
Fertilizer	2	9.693**	73.928**	0.000	0.588	56.600**	5.592**	43.037**
V x F	4	0.430**	0.957*	0.002**	0.103	0.753	1.934	9.137**
Rest	16	0.045	0.190	0.000	0.197	1.081	1.081	0.541

* significant with $P < 0.05$; ** significant with $P < 0.01$.

The land race variety had significantly higher ($P < 0.05$) OM, OMD and DNDF values than Indaf 8 and PR 202, and although this was consistent across the three fertility levels the differences were small in biological terms. Across the three fertility levels, the total biomass remained more or less the same for all three cultivars. Fodder yield was generally higher ($P < 0.05$) for landrace, while grain yields were lower ($P < 0.05$) for this variety (see Table 2). This is suggestive of the fact that grain yield has been improved at the cost of fodder yield.

Table 2 Effect of variety and fertilization on seven characters in fingermillet

Characters	Varieties	Fertility			Mean
		F1	F2	F3	
Grain yield (1000 kg DM/ha)	Indaf 8	2.06	3.74	4.47	3.42a
	PR 202	2.41	4.10	4.88	3.79b
	Landrace	1.85	2.47	3.10	2.47c
	Mean	2.10a	3.44b	4.15c	
Fodder yield (1000 kg DM/ha)	Indaf 8	4.13	7.90	9.64	7.22a
	PR 202	6.02	9.11	10.80	8.64b
	Landrace	5.41	10.63	11.70	9.27c
	Mean	5.19a	9.22b	10.73c	
Harvest index (%)	Indaf 8	0.32	0.33	0.32	0.32a
	PR 202	0.29	0.31	0.31	0.31b
	Landrace	0.25	0.19	0.21	0.22c
	Mean	0.29a	0.28b	0.28b	
Organic matter (% of DM)	Indaf 8	87.7	88.2	88.4	88.1a
	PR 202	88.7	89.2	89.3	89.1b
	Landrace	90.1	90.5	90.2	90.3c
	Mean	88.8a	89.3a	89.3a	
NDF (% of DM)	Indaf 8	68.1	66.1	66.7	66.0a
	PR 202	68.8	67.4	64.3	66.9a
	Landrace	69.4	67.0	63.3	66.6a
	Mean	68.8a	66.9b	63.8ab	
OMD (%)	Indaf 8	60.7	59.5	61.6	60.6a
	PR 202	60.2	59.4	59.8	59.8a
	Landrace	63.7	61.0	61.7	62.1b
	Mean	61.5a	60.0b	61.0ab	
NDFD (%)	Indaf 8	49.2	48.0	48.5	48.5a
	PR 202	48.7	46.3	44.0	46.3b
	Landrace	52.8a	47.4b	45.4c	48.6a
	Mean	50.2a	47.2b	46.0c	

Note: Different letters indicate significant effects at $P < 0.05$

Variability and genetic architecture of straw quality characters in fingermillet

Plant height, fodder and grain yield, HI, stem and leaf percentage, organic matter contents of the straw and nitrogen of 42 fingermillet genotypes of diverse growth durations were studied. Even in the limited material studied, the genotypic differences for all the above characters were highly significant (see Table 3). The mean, range, variability, heritability and genetic advance have been presented in Table 4. The genotypic coefficient of variability was low for most of the fodder characteristics except for nitrogen indicating the presence of fair amount of genetic variation in the material studied and scope for possible improvement.

The heritability of all characters was high except for OM. The relatively moderate variability even in the limited material studied, is indicative of much larger variation for straw quality parameters in the world collection of germplasm maintained at Bangalore.

Table 3 Analysis of variance for eleven characters in fingermillet as affected by genotype

Source	df	Mean squares										
		Plant height	Stem % age	Leaf % age	Organic matter	OMD	NDF	NDFD	Nitrogen content	Fodder yield	Grain yield	Harvest index
Replications	2	25.31	1.59	0.85	1.84	1.11	3.05	0.30	0.01	0.30	0.26	8.99
Treatments	41	772.81**	48.23**	42.46*	2.42**	23.00**	31.83**	7.57**	0.04**	2.89**	2.08**	71.56**
Rest	82	35.21	6.90	2.11	0.94	1.16	2.16	2.05	0.01	0.36	0.21	6.43

Table 4 Mean, range, phenotypic and genotypic variability, heritability and genetic advance of eleven characters in 42 fingermillet cultivars

	Mean	Range	PCV	GCV	Heritability	Genetic advance
Plant height (cm)	101	60 - 128	16.61	15.54	0.87	30.31
Stem percentage	58	51 - 67	7.79	6.36	0.66	6.24
Leaf percentage	42	34 - 49	9.43	8.77	0.86	7.02
Organic matter (% of DM)	90.5	86.6 - 92.0	1.32	0.78	0.34	0.85
OMD (%)	59.6	53.4 - 65.8	4.87	4.50	0.86	5.16
NDF (% of DM)	62.6	56.1 - 71.4	5.55	5.03	0.82	5.87
NDFD (%)	41.6	38.4 - 45.6	4.75	3.26	0.47	1.92
Nitrogen content	0.6	0.4 - 0.8	18.28	17.65	0.93	0.21
Fodder yield (t/ha)	6.6	4.7 - 8.9	16.58	13.86	0.70	1.58
Grain yield (t/ha)	4.7	3.1 - 6.1	19.23	16.66	0.75	1.41
Harvest index (%)	42 3	30.1 - 51.0	12.54	11.02	0.77	8.43

Notes: PCV = phenotypic coefficient of variation
GCV = genotypic coefficient of variation

Relation among grain yield, fodder yield and other related attributes

The genotypic association of fodder and grain yield with other quality parameters of straw is presented in Table 5. The data indicate positive association of grain and fodder yield and suggest the possibility of simultaneous improvement in crop breeding programs. The work of Badve *et al.* (1993) also shows that in sorghum a higher straw yield does not imply a decreased straw quality. Fodder yield as expected shows positive association with plant height and negative association with HI. Among the indicators of nutritive value, only NDFD showed negative association, while all other nutritive values were independent of fodder yield. In contrast grain yield has a significant negative association with stem percentage, OMD, NDFD and nitrogen content. The relationships demonstrate the possibility of improving fodder yield and grain yield simultaneously in fingermillet. As fodder yield is independent of other quality parameters, selection directed for increasing fodder yield is unlikely to affect the nutritive value of the straw adversely.

Table 5 Genotypic correlation for eleven characters in 42 cultivars of diverse growth durations of fingermillet

Character	Plant height	Stem (%)	Leaf (%)	OM	OMD	NDF	DNDF	Nitrogen content	Fodder yield	Grain yield	Harvest index
Plant height	1.00	-0.30	0.35	0.38	-0.55	0.51	-0.57	-0.50	0.66	0.77	0.24
Stem %		1.00	-0.99	-0.19	0.51	-0.44	0.52	0.36	0.07	-0.52	-0.46
Leaf %			1.00	0.29	-0.56	0.54	-0.47	-0.41	-0.05	0.55	0.49
Organic matter				1.00	0.23	-0.69	0.08	-0.16	0.10	0.09	-0.17
OMD					1.00	-0.91	0.77	0.62	-0.08	-0.64	-0.62
NDF						1.00	-0.42	-0.60	-0.05	0.58	0.67
NDFD							1.00	0.50	-0.32	-0.57	-0.28
Nitrogen content								1.00	-0.06	-0.79	-0.73
Fodder yield									1.00	0.40	-0.41
Grain yield										1.00	0.66
Harvest index											1.00

Notes: OMD = Organic matter digestibility
NFD = Cell wall content
NDFD = Digestibility of cell wall content

CONCLUSIONS

Genotypic correlations provide a measure of association among the attributes and serve as indicators in indirect selection, though the interpretation is not always the same for animal breeders as for plant breeders. Considerable variability even within the limited material studied has been recorded for both fodder yield and quality. This indicates the possibility of variability in the germplasm accession not studied so far. Positive association of grain yield and fodder yield and a nonsignificant association of fodder yield with other fodder quality parameters do not preclude the possibility of developing cultivars with high grain and fodder yield possessing acceptable fodder quality characteristics. It is worthwhile assessing the world collection of 4500 germplasm maintained at the Project Coordinating Unit (Small Millets), GKVK, Bangalore, for identifying source material possessing high grain and fodder quality for future breeding programs.

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VARIATION IN QUALITY OF SORGHUM STOVER

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SUMMARY

In experiments with sorghum straw, it was observed that variability between varieties existed with regard to NBOMD. Hybrids and improved varieties did not differ much with regard to quality of straw and grain yield, but the improved varieties had a much higher straw yield than hybrids. Leaves had in most experiments a higher NBOMD and a higher rate of degradation than stems. Significant differences between years and locations were observed. Varieties grown in post-monsoon seasons had higher NBNDFD than monsoon varieties. No significant negative correlations existed between yields of grain or fodder and NBOMD. It was concluded that relevant traits such as leaf content and DOMI in relation to NBOMD should be studied.

INTRODUCTION

Sorghum (*Sorghum bicolor*) is an important crop (Doggett, 1988), in rainfed regions of India (ICAR, 1980). The estimated availability of the grain and stover is reported by Singh and Rangnekar (1986). Crop residues in general are poor quality roughages, but upgrading is possible by treatment (Sundstol and Coxworth, 1984; Owen and Jayasuria, 1989). Another approach towards the same end could be selection of varieties which combine better quality straw with high grain and fodder yield. Variability in the nutritive value of crop residues of cereals has been reported (Ørskov, 1988; Capper *et al.*, 1988a; Reed *et al.*, 1988). This paper summarizes results of variability studies with different varieties of sorghum.

MATERIALS AND METHODS

In order to study the genetic variability in sorghum straw, samples were collected from trials conducted at the Mahatma Phule Agricultural University (MPAU), Rahuri, Maharashtra, India. The samples consisted of 22 cultivars of monsoon season and 8 cultivars of post-monsoon season. While the monsoon cultivars (11 hybrids (H) and 11 improved varieties (IV)) were from three locations, the post-monsoon cultivars (3 hybrids and 5 improved varieties) were from 2 locations. The agronomic practices adopted at each location were the same. The samples were separated into leaf and stem fractions dried at 65°C in a forced air draft oven and ground through a 2 mm screen. The year to year variation in digestibility of sorghum straw cultivars was studied with 9

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monsoon cultivars (4 improved varieties and 5 hybrids) grown in two succesive years (1988 and 1989) under similar management conditions at MPAU, Rahuri. The samples were separated into morphological parts, dried and ground as before.
In case data are presented without distinction between leaf and stem a leaf to stem ratio of 1 : 1 was applied to estimate the data for the whole harvested straw.

Dry matter and ash of the samples were determined according to AOAC (1975) and ash-free NDF was determined by the method of Goering and van Soest (1970). The digestibility of organic matter (NBOMD) and NDF (NBNDFD) was measured by incubating 3 g samples in nylon bags (75 * 90 mm, 40 um pore size) for 48 hours in three rumen cannulated cattle in two separate runs. The bags were washed in a washing machine and dried at 65° C and the residues were analysed for DM, ash and NDF. Kinetics of degradation was studied with samples from monsoon cultivars pooled per location. For this experiment the incubation period in the rumen was 3, 6, 12, 24, 48 and 210 hours in three animals. The data were fitted to the equation of Ørskov and McDonald (1979). The data were analysed statistically by analysis of variance for differences between varieties, types, seasons, years and locations.

RESULTS AND DISCUSSION

Varietal effects and differences between plant parts

A wide range for N and OM content in leaves and stems for sorghum varieties grown in two seasons (monsoon and post-monsoon) in Maharashtra is shown in Table 1. Samples were pooled over locations. Leaves had a higher N and lower OM and NDF content than stems. The post-monsoon varieties had lower N content than monsoon varieties, which could partly be due to lower N fertilization in post-monsoon season (80 and 60 kg/ha for monsoon and post-monsoon seasons, respectively). The NDF-content was also higher for post-monsoon varieties than for monsoon varieties. The biomass yield was higher for monsoon varieties than for post-monsoon varieties. Therefore, dilution of nutrients due to a higher growth could not be the reason of the lower N content from post-monsoon varieties compared with monsoon varieties.

Table 1 Chemical composition of sorghum stover

Season	No of samples	Plant part	N	OM	NDF
				% DM	
Monsoon	22	Stem	0.42	94.5	63.6
		Leaf	0.71	87.4	59.1
Post-monsoon	8	Stem	0.32	94.6	76.5
		Leaf	0.47	86.3	69.9

The variation in the 48-hour NBNDFD of leaves and stems is presented in Table 2. The study included samples pooled over three locations of 11 improved varieties and 11 hybrids. NBNDFD varied significantly within improved varieties (IV) and hybrids (H), but not between IV and H. The NBNDFD was higher for leaves than for stems but the differences were small as compared to other cereals (Capper *et al.*, 1988a). Reed *et al.* (1988) observed NBNDFD of sorghum leaves to be 4 - 7 units higher than of stems, differences which are similar to ours. The cell solubles (OM minus NDF) as % of OM were similar for the plant parts within monsoon varieties (33%) and post-monsoon varieties (19%), indicating that the only differences in digestibility were likely to be between the cell wall components.

The correlation coefficients for various plant characteristics and NBOMD are given in Table 3 for monsoon and post-monsoon varieties pooled over locations. Within improved varieties or hybrids none of the correlations studied were significant, but in the combined data set total biomass yield was positively correlated with NBOMD for monsoon and post-monsoon varieties and fodder yield was positively correlated with NBOMD for monsoon varieties. No significant correlations were observed between NBOMD and grain yield, harvest index or plant height.

Table 2 Variation in NDF digestibility in sorghum cultivars

Plant part	Hybrids	Improved varieties
Leaf	58.7**	58.5**
	(53.6-64.4)	(55.3-62.4)
Stem	55.1**	55.9**
	(52.1-59.1)	(49.0-58.5)

Notes: ** within hybrids or improved varieties the differences due to cultivars were significant ($P < 0.01$)
figures in parentheses indicate range

Table 3 Correlation coefficients between plant characteristics and NBOMD

	Monsoon (n = 22)	Post-monsoon (n = 8)
Biomass yield	0.42*	0.73*
Grain yield	-0.02	0.38
Fodder yield	0.45*	0.39
Harvest Index	-0.33	0.04
Plant height	0.05	0.36

Notes: * *significant with* $P < 0.05$

Comparison of hybrids and improved varieties

Digestibility, composition and yield characteristics for improved varieties and hybrids are shown in Table 4. Analysis of composition and digestibility was done on samples pooled over locations. IV had a higher content of solubles than H, while the NBNDFD was similar in both. The significant difference in NBOMD between IV and H could thus partly be explained by the higher NDS content of IV compared with H. The difference in NBOMD is, however, lower than the mean difference in the NDS content of the OM. This is explained by the higher NDF content of the OM of the hybrids. The NDF content of OM of leaves as well as of stems of hybrids was higher than of improved varieties. This small difference between hybrids and improved varieties could become important when the IV and H differ largely in leaf:stem ratio. If plant height is assumed to be correlated with leafiness (Capper, 1988a; Capper *et al.*, 1988b) the difference in leafiness between IV and H are unlikely to be wide as the plant height was not significantly different between IV and H.

The large difference in fodder yield between IV and H was an important feature. With almost similar grain yield improved varieties produced approximately 20% more fodder of slightly better quality than hybrids.

Table 4 Comparison of hybrids and improved varieties

Type	NBOMD (%)	NDFD (%)	NDS (% OM)	Fodder yield (DM kg/ha)	Grain yield (kg/ha)	Plant height (cm)	Harvest index
Hybrids	63.6	56.1	30.6	7966	3326	180	0.29
Varieties	66.2	56.2	34.7	9654	3265	175	0.25
Significance	**	ns	**	***	ns	ns	**

Notes: ** significant with $P < 0.01$
*** significant with $P < 0.001$

Season effects

Sorghum is grown in two different seasons (monsoon and post-monsoon). The cultivars recommended for the seasons are different. It is the general opinion of farmers that straw from post-monsoon cultivars is 'better' than that from monsoon cultivars. The data of 22 monsoon and 8 post-monsoon cultivars pooled over locations indicated a higher NDF content and NBNDFD for post-monsoon than for monsoon cultivars (Table 5). Higher temperature during growth as found during monsoon increased NDF content and decreased the NBNDFD in maize (Deinum, 1976), but this does not seem to be a general relationship. Differences in the response to higher temperature during growth have been reported for tropical and temperate grasses by Ford *et al.* (1979), who observed decreased NDF due to a higher temperature in 12 out of 13 tropical grasses, while an inverse trend was seen in temperate species.
The harvest index (HI) (grain yield/total biomass yield) for the post-monsoon cultivars (0.27 - 0.41) was higher than for the monsoon cultivars (0.20 - 0.32). This may have been responsible for the higher NDF content of post-monsoon cultivars, although

the correlation between HI and NDF content was not significant in the present data.

Reed *et al.* (1988) observed a lower NDF content in leaves in sorghum grown in a warmer climate with an inverse trend for stems. They further noted 8 - 12 units decline in the NDFD of leaf sheath for crops grown in a warmer location.

Table 5 Effect of season of growth on NDF content and digestibility

	Monsoon (n = 22)	Post-monsoon (n = 8)
NDF (%)	61.4	73.2
NDFD (%)	57.1	69.0

Year effect

The year effect was studied for 9 cultivars of monsoon season sorghum. In 1988 there were 46 rainy days with 735 mm rainfall while in 1989 these were 34 and 683, respectively. The results, are presented in Table 6.

No significant differences in NBOMD or NBNDFD were observed between years. Cultivars showed more variation in 1989 than in 1988.
The correlation between years was low (0.57) and not significant, which was possibly due to the low variation in 1988. Later studies, including data from the same cultivars grown in 1990 showed a strong genotypic effect and insignificant genotype * year interactions. Ørskov (1988) reported variety * year interaction for winter wheat, oat straw and spring barley straw, but not for winter barley straw.

The content of cell solubles of the sorghum stover grown in the two years was higher and more variable in 1989 than in 1988.

Table 6 Effect of year on percentage NBOMD and NBNDFD of sorghum straw for 1988 and 1989

	NBOMD		NBNDFD	
	1988	1989	1988	1989
Average	66.7	66.6	57.7	55.6
Standard deviation	1.73	4.09	2.12	4.00

Location effects

The data on degradation parameters was analysed according to the model of Ørskov and McDonald (1979):

$$P = A * (1 - e^{-kt}) + C$$

A = Degradable fraction at time t
k = Rate constant
C = Readily soluble fraction
P = Degradability at time t

The effective digestibility (D) was calculated by the formula of as given below, where in k_p (rate of passage through the rumen) was assumed to be 3 % per hour.

$$D = C + (A * k / (k + kp))$$

For the analysis all samples were pooled per location.
The location effect on the rate of degradation (k) was not significant, while for the other parameters some location differences were observed.

While comparing the fractional degradation rates (k) of OM and NDF for plant parts, leaf showed higher k (3.1 and 3.0 for OM and NDF, respectively) than stem (2.0 and 2.1 for OM and NDF, respectively). In further studies (Thole *et al.*, unpublished) effect of location on digestibility was studied in 6 improved varieties and 4 hybrids of post-monsoon season. The results indicated (Table 8) no effect of location on quality of stems, but leaves in Karad were more digestible than leaves in Rahuri and stems in both locations (P < 0.01). Experiments to investigate the importance of genotype * location interactions are yet to be conducted.

Table 7 Degradation parameters of sorghum straw OM and NDF in different locations

Parameters	Locations					
	1		2		3	
	OM	NDF	OM	NDF	OM	NDF
A	43.0	56.9^a	43.7	63.0^b	40.8	56.3^a
K	2.4	2.4	2.8	2.7	2.5	2.6
C	37.4	19.3^b	38.5	12.8^a	41.7	20.7^b
D	55.9^a	44.3^a	59.5^b	42.9^a	60.4^b	46.7^b

Note: means with different superscripts within OM or NDF differ significantly (P < 0.05)

Table 8 NBOMD and NBNDFD of Sorghum plant parts of two locations

Location		Karad	Rahuri	Significance
Stems	NBOMD (%)	66.4 (4.8)	65.8 (4.1)	ns
	NBNDFD (%)	55.0 (3.7)	55.2 (4.3)	ns
Leaves	NBOMD (%)	72.8 (1.8)	66.9 (2.2)	**
	NBNDFD (%)	60.7 (2.1)	54.8 (2.2)	**

figures in parentheses indicate standard deviation

CONCLUSIONS

Differences in the nutritive quality of sorghum stover occur due to genotype and environmental factors such as location and season of growth. The results of the studies indicate, that selection of cultivars with a high straw quality is possible. Improved varieties showed a higher straw yield with a better quality than hybrids, while the grain yield of both types of cultivars were equal. Within types of cultivars selection could probably be for leafier cultivars, since leaves have a higher rate of degradation than stems, which is assumed to be positively related with intake. However, relatively small differences in digestibility were observed between leaves and stems. Leaves are known to contain more phenolics than stems and the effect of these phenolics on intake should be further investigated.

The importance of interactions between genotype and growth environment with regard to quality is not known yet, but preliminary results indicate, that genotype * year interactions are of low importance. However, selection should be based on analysis of cultivars grown in a number of years and locations because the variation between cultivars may vary from one growth environment or year to the other.

No significant negative correlations between quality and yield parameters were observed as was also reported by Capper (1988a). This means, that a good fodder quality and high yields of straw and grain could be combined in one cultivar. Of course grain and fodder yield are complementary as soon as the biological limit of biomass production is reached, but in those farming systems where straw is an important resource cultivars with a high straw yield should be available.

It is important to investigate wether differences in quality as found with *in sacco* analysis are also reflected in differences in *in vivo* DOMI.

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GENETIC AND MANAGEMENTAL EFFECTS ON VARIABILITY OF STRAW QUALITY FROM FINGERMILLET (*Eleusine Coracana*)

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SUMMARY

The genetic variation in straw quality of fingermillet and the effects of location, management and NPK fertilization on quality of fingermillet straw was studied in four experiments. In experiment I, 42 cultivars of 3 genetic groups differing in days to maturity (Short, Medium and Late) were studied to assess the genetic variability. The short duration cultivars had significantly (P < 0.01) higher N content, lower NDF content, higher IVOMD and IVNDFD than the medium and late duration cultivars. The IVNDFD of leaves was significantly (P < 0.01) higher than that of stems. In experiment II, 21 cultivars grown at three locations with different soil and climatic conditions showed a wide difference in grain production, height, stem weight, OM and NDF content and IVNDFD of straw. In experiment III, three cultivars were harvested from anthesis to grain maturity or were kept as a standing crop for ten days after maturity. Straw harvested at maturity was also stored under roof over a period of 5 months. NDF content increased (P < 0.05) with plant maturity, and kept increasing during storage. The IVOMD and IVNDFD declined with age before or after harvest (P < 0.05). In Experiment IV, application of NPK (0 : 0 : 0, 50 : 25 : 25 and 100 : 50 : 50) increased the total biomass production per hectare without altering the harvest index of three genetically different cultivars (Indaf-8, PR-202, and Hullubele). The OM content and IVOMD remained unchanged, while the NDF content and IVNDFD decreased (P < 0.01) with increasing level of NPK. The traditional variety (Hullubele) known for fodder production had a bettter straw IVOMD than the improved varieties. It was concluded, that the quality of fingermillet straw in terms of IVOMD was affected by parameters such as genotype, location, moment of harvest, storage and fertilization.

INTRODUCTION

Fingermillet (*Eleusine Coracana*) straw is an important fodder for cattle in many parts of India. It is grown as a dryland crop as well as under irrigation in the southern parts of India. Depending on the onset of monsoon (June - October) early (below 90 days), medium (100 - 110 days) or late (above 110 days) maturing varieties are sown. Since 1950, there has been a breeding policy to increase grain production, resulting in the release of several high grain yielding cultivars. This has been associated with a reduction in fodder yields. For example, the

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traditional variety of Hullubele (local) has a harvest index (grain as a fraction of total above ground biomass) of about 0.21, whereas in the improved varieties (Indaf series) the harvest index is about 0.4, while the total biomass yield of traditional and improved varieties does not differ much (Gowda *et al.*, 1988).

In some farming systems the straw has a low value compared to grain, but in others the grain and fodder value can be equally important (Kelley *et al.*, 1991; De Wit *et al.*, 1993). It is therefore desirable to develop methods for improving straw quality and/or straw yield. Several methods have been suggested to improve the low nutritive value of straw, such as physical, chemical and microbial treatments. Very few of these have become popular on small farms due to technical or other constraints. One alternative is to develop dual purpose cultivars which satisfy the farmers' requirement for grain yield and straw yield, the latter in terms of quantity and quality.

Throughout the world attempts are being made to evaluate differences in straw quality arising from varietal differences or managemental practices. A wide range of variability in composition and digestibility was reported for rice straw (Doyle *et al.*, 1986) and for wheat, barley and oats (Kernan *et al.*, 1979; Capper *et al.*, 1988; Ramanzin *et al.*, 1986; Pearce *et al.*, 1988; Ceccarelli *et al.*, 1993) and for maize (Deinum, 1986-87). Similarly Baig *et al.* (1981), and McIntire *et al.* (1988), identified superior cultivars in *Sorghum bicolor* fodder. The information available with regard to variation in quality of fingermillet straw is, however, very scanty.

The objective of the studies reported in this paper is to evaluate the possibility of breeding for fingermillet straw quality and to get information about environmental and managemental factors affecting quality of fingermillet straw. The studies were undertaken in collaboration with All India Small Millets Improvement Project (ICAR), Gandhi Krishi Vigyan Kendra, Bangalore.

GENETIC VARIABILITY

Genetic variability in fingermillet straw was studied on 42 varieties belonging to 3 genetic groups viz., early (13), medium (16) and late (13) maturing. These varieties were grown in triplicate under protective irrigation at GKVK, Bangalore. In all trials grain harvesting was done by removal of ear heads and straw was harvested about 3 cms. above the ground level on the same day as the grain. For details about analysis of heritability and other genetic parameters derived from this experiment is referred to Seetharam *et al.* (1993).

Grain and fodder yield and consequently total biomass yield per hectare and height increased ($P < 0.01$) with duration till maturity (see Table 1). Genotypic effects within duration classes were observed for all parameters given in Table 1 for early maturing varieties, for height in medium and for height and harvest index in late maturing varieties.

In Table 2 the composition and *in vitro* digestibility of straw of the various duration classes of fingermillet are given as well as the significance of the genotypic effects within duration class.

No significant differences were found between duration classes in OM content, but the NDF content increased with duration. The N content was significantly higher in early maturing varieties than in the other duration groups. Digestibility decreased significantly with duration. Genotypes differed significantly with regard to OM content and OMD within all duration classes, while NDFD and N content did not differ within duration classes between varieties. The NDF content differed between genotypes within the early and medium maturing varieties.

Table 1 Grain and fodder yield, harvest index and height of fingermillet varieties

Characters	Duration			Significance of genotype effect		
	Early	Medium	Late	Early	Medium	Late
Grain yield (t/ha)	3.8^{a}	4.9^{b}	5.5^{c}	**	ns	ns
Fodder yield (t/ha)	6.1^{a}	6.4^{a}	7.3^{b}	**	ns	ns
Harvest index	0.39^{a}	0.44^{b}	0.44^{b}	**	ns	*
Height (cm)	88.6^{a}	101.2^{b}	115.0^{c}	**	**	**

Notes: Means with different superscripts per row differ significantly ($P < 0.05$)
Genotypic effects: * $P < 0.05$
** $P < 0.01$

Table 2 Chemical composition and in-vitro digestibilities of the whole straw

Characters	Duration			Significance of genotype effect		
	Early	Medium	Late	Early	Medium	Late
Composition (% DM)						
Organic matter	90.3	90.6	90.8	**	**	*
Nitrogen	0.71^{b}	0.54^{a}	0.55^{a}	ns	ns	ns
NDF	59.7^{a}	62.8^{b}	65.2^{c}	**	**	ns
Digestibility (%)						
Organic matter	62.1^{c}	59.3^{b}	57.5^{a}	**	**	**
NDF	42.7^{b}	41.2^{ab}	40.8^{a}	ns	ns	ns

Note: means with different superscripts per row differ significantly ($P < 0.05$)
Genotypic effects: * $P < 0.05$
** $P < 0.01$

It can be postulated that cell contents are the main determinant of variation in OMD between varieties, since the NDFD did not differ much between duration classes. The relatively larger differences in OMD could consequently be explained by the decreased NDS content with duration. It was further found, that the correlation between cell contents and IVOMD was around 0.8 within each of the three duration classes.

Thus, the lower NDS content and consequently higher NDF content in late maturing varieties of fingermillet resulted in lower digestibility. This is in agreement with findings for rice straw varieties (Roxas *et al.*, 1984; Sannasgala and Jayasuria, 1984).

MORPHOLOGICAL FRACTIONS OF STRAWS

It has been suggested that variability in straw composition and digestibility is associated with the proportion of morphological fractions for barley straw (Ramanzin *et al.*, 1986), for oat and wheat straw (Shaud *et al.*, 1987), for rice straw (Devendra *et al.*, 1986) and for barley and wheat straw (Capper *et al.*, 1988). The stem and leaves were separated from six varieties belonging to three duration groups and examined for NDF content and digestibility. NDF of leaf (66.3%) was significantly ($P < 0.01$) lower compared to stem (70.6%). The IVNDFD was significantly ($P < 0.01$) higher in leaves (50.6%) compared to stem (33.4%). This was also true for digestible NDF in leaf (39.5%) as against in stem (25.3%) despite the lower NDF in leaf. Whether these differences in digestibility of leaves and stems is also reflected in differences in DMI should be the subject of further studies.

EFFECT OF LOCATION

In a trial conducted during 1988 - 1989, 21 cultivars were grown on three locations having distinct soil and climatic difference viz., Tamil Nadu (Coimbatore: red soils, rainfall 423 mm), Andhra Pradesh (Vizayanagaram: sandy soils, rainfall 1141 mm) and Karnataka (Bangalore: red lateritic soils, rainfall 576 mm). The straw varieties were analysed for yield, composition and quality (see Table 3).

This is probably also true for straw yield, which was not recorded, but which is related to plant height and stem weight grain yield which was highest in Bangalore. Genotypic differences existed with regard to the yield parameters. Small, but significant differences in composition existed between locations, but no genotypic differences were observed in composition. The IVOMD did not differ between locations, but small differences in NDFD were observed. More NDF seemed to be compensated by a higher NDFD. Genotypes did not differ significantly in digestibility of OM or NDF. The information about growth conditions was insufficient to explain the differences in yield, composition and IVNDFD between locations.

Table 3 Yield, chemical composition and *in vitro* digestibility

Character	Significance of genotypic effect	Location		
		Coimbatore	Vizayanagaram	Bangalore
Grain yield (T/ha)	***	1.3^{b}	1.8^{b}	5.0^{a}
Plant height (cm)	***	73^{c}	81^{b}	94^{a}
Stem weight (g/plant)	***	2.3^{b}	2.5^{b}	3.8^{a}
Composition (%DM)				
Organic matter	ns	87.5^{b}	87.9^{b}	88.2^{a}
Nitrogen	ns	1.5^{a}	0.6^{c}	1.1^{b}
NDF	ns	64.1^{c}	67.8^{a}	65.9^{b}
In vitro Digestibility (%)				
Organic matter	ns	51.4	51.6	51.2
NDF	ns	33.8^{b}	37.1^{a}	34.5^{b}

Note: means with different superscripts per row differ significantly ($P < 0.05$)

EFFECT OF MANAGEMENT

The effect of different stages of harvesting on the composition of fingermillet as a forage crop was studied. The three tested varieties were a local traditional variety called by farmers as Hullubele with an average HI - 0.21, a variety PR-202 improved from the local variety (average HI 0.40) and an Indo-African hybrid variety - Indaf-8 (HI - 0.41). These varieties were grown in three replicates in randomized block design during monsoon season (July - October). Samples of the crop were analysed at the following stages of growth:

M-1 - Anthesis stage: (50% flowering - 70 days after sowing for Hullubele and PR-202 and 75 days after sowing for Indaf-8).

M-2 - Dough stage (88 days after sowing for Hullubele and PR-202 and 90 days after sowing for Indaf-8).

M-3 - Grain maturity stage (120 days after sowing for Hullubele and PR-202, 138 days after sowing for Indaf-8)

M-4 - Ten days after grain maturity (after removal of ear heads as in M-3, straw left standing in the field).

To study losses during storage a part of the straw harvested at grain maturity (M-3) was sun dried (for 1-2 days) and stored under roof condition to assess storing effects for 60 (M-5) and 150 days (M-6). The results are presented in Tables 4 and 5.

There was a drastic decline of IVOMD as the plant neared harvest period for all three varieties (Table 4). A similar observation was made by Roxas *et al.* (1988) with rice straws. The decrease of OMD for improved varieties (Indaf-8 and PR-202) was greater than for Hullubele from anthesis to grain maturity. The decrease in OMD from grain maturity during storage upto five months was high for all straws with at least 10% units loss in digestibility.

The OM content did not vary much between treatments. NDF increased with maturity before grain maturity and during the first 60 days of storage (M-5 compared to M-3), but the NDF content did not change much from 60 (M-5) to 150 days (M-6) of storage. This indicates that losses of cell solubles happened during the first part of storage. IVOMD and IVNDFD decreased with the stage of maturity. The reduction of IVOMD may be attributed to loss of cell solubles and decrease of the IVNDFD. The reduction of NDFD during storage may be due to losses of leaf. Losses of cell solubles may be attributed to grain filling before grain maturity and to respiration during drying after harvest.

Table 4 Chemical composition and *in vitro* digestibility

Constituents (%)	M-1	M-2	M-3	M-4	M-5	M-6
			Indaf-8			
Organic Matter	88.2	88.2	87.5	89.7	87.6	87.2
NDF	59.1	57.1	65.0	67.5	69.2	68.1
IVOMD	75.0	72.2	61.5	58.4	51.6	51.4
IVNDFD	62.6	57.1	48.1	44.7	38.7	37.8
			PR - 202			
Organic Matter	90.2	90.2	89.1	90.3	88.5	88.0
NDF	58.6	60.8	67.5	69.3	72.0	71.5
IVOMD	73.5	66.7	58.4	55.5	48.3	46.8
IVNDFD	59.1	50.5	45.7	42.0	36.4	34.5
			Hullubele			
Organic Matter	89.1	90.7	90.5	90.6	90.0	88.8
NDF	59.3	59.5	67.0	68.6	73.1	72.0
IVOMD	73.6	69.2	62.8	56.0	49.6	48.0
IVNDFD	60.4	53.1	49.6	41.7	38.0	35.7

Table 5 Means per treatment and statistical significance

Stage	Organic matter (% of DM)	NDF (% of DM)	IVOMD (%)	IVNDFD (%)
M-1	89.2^{bc}	59.0^{c}	74.0^{a}	60.7^{a}
M-2	89.7^{ab}	59.1^{c}	69.4^{b}	53.6^{b}
M-3	89.0^{bcd}	66.5^{b}	60.9^{c}	47.8^{c}
M-4	90.2^{a}	68.5^{b}	56.6^{d}	42.8^{d}
M-5	88.7^{cde}	71.4^{a}	49.8^{e}	37.7^{e}
M-6	88.0^{e}	70.5^{a}	48.7^{e}	36.0^{e}

Note: different superscripts a, b, c, d, e means significant ($P < 0.05$) when varieties pooled for age group

EFFECT OF NPK APPLICATION

Previous studies conducted by Erikson (1981), Biswas and Choudhury (1981), Roxas *et al.* (1985), and Sannasgala *et al.* (1985), have shown that application of N to soils tends to increase the N content of straws, but has variable effects on NDF and IVOMD. However, it is thought that the increase in N content of the straw might positively affect the dry matter intake and in-vivo digestibility. The effect of other fertilizers on straw quality is not yet clear. An earlier study carried out at NDRI, Bangalore on fingermillet cultivars on three levels of nitrogen (50, 75 and 100 kg/ha) revealed no effect on the IVOMD of straw (Subba Rao *et al.*, 1988).

In the present experiment the effect of three levels of NPK on composition and digestibility of fingermillet straw was studied. The three varieties (Indaf-8, PR-202, and Hullubele) belonging to distinct genetic characters were grown in a RBD with three replicates on red soils.
Three levels of NPK were applied under irrigated conditions (kg/ha):
- (T1): 0, 0, 0,
- (T2): 50, 25, 25,
- (T3): 100, 50, 50.

Grain, fodder yield and straw qualities as revealed on three levels of fertilizer application are summarized in Tables 6 and 7. See also Seetharam *et al.* (1993) for information about this experiment.

Table 6 Grain, fodder yield, chemical composition and IVOMD

Character	Indaf-8	PR-202	Hullubele
		Treatment - T1	
Grain yield (T/h)	1.96	2.41	1.85
Fodder yield (T/h)	4.13	6.02	5.41
Harvest index	0.32	0.29	0.25
Organic Matter (%)	87.7	88.7	90.1
NDF (%)	67.8	68.8	69.4
IVOMD (%)	60.7	60.2	63.7
IVNDFD (%)	49.2	48.7	52.8
		Treatment - T2	
Grain yield (T/h)	3.74	4.10	2.47
Fodder yield (T/h)	8.0	9.11	10.63
Harvest index	0.32	0.32	0.20
Organic Matter (%)	88.2	89.2	90.5
NDF (%)	66.1	67.0	67.0
IVOMD (%)	59.5	58.7	61.0
IVNDFD (%)	45.9	46.2	47.4
		Treatment - T3	
Grain yield (T/h)	4.47	4.88	3.10
Fodder yield (T/h)	9.64	10.80	11.76
Harvest index	0.32	0.32	0.21
Organic Matter (%)	88.2	89.3	90.2
NDF (%)	63.7	64.3	63.3
IVOMD (%)	61.6	59.8	61.7
IVNDFD (%)	46.8	44.2	45.4

Table 7 Effect of fertilization (means of three varieties)

Parameters	Levels of fertilizers		
	(T1)	(T2)	(T3)
Grain yield (kg/ha)	2100[c]	3400[b]	4200[a]
Fodder yield (kg/ha)	5200[c]	9200[b]	10080[a]
Harvest Index	0.29	0.28	0.28
Composition (% DM)			
Organic matter	88.8	89.3	87.3
NDF	68.6[a]	66.8[b]	63.8[c]
In-vitro digestibility (%)			
Organic matter	61.5	60.0	61.0
NDF	50.2[a]	46.5[b]	45.4[b]

Note: different superscripts a, b, c means significant (P < 0.05)

Grain yield significantly (P < 0.05) responded to NPK fertilization, but more in case of Indaf-8 and PR-202 than in case of the local variety Hullubele. A reverse trend was noticed for straw yield, i.e. straw yield increased more in the local variety than in the new varieties after fertilization. The OM content and OMD was higher (P < 0.05) in the local variety which had lower harvest index (0.23) compared to hybrids (0.32). The NDF content was not very different between varieties indicating the small improvement in OMD of the traditional straw was due to more digestible NDF.

The grain and fodder production (biomass) per hectare increased with the level of application of NPK (P < 0.05). The improved varieties Indaf-8 and PR-202 produced more grain and the local (traditional) variety yielded more fodder. The different levels of NPK application did not alter the harvest index.

The OM content and OMD remained unchanged (see Table 7), while NDF content and NDFD decreased (P < 0.05) with increasing level of NPK application. This study indicates that higher dosages of fertilizer (NPK) tend to enhance total biomass per unit area, without affecting straw quality as is seen by IVOMD. The total amount of energy available as animal feed, namely fodder yield * IVOMD, was significantly increased when more fertilizer was applied. Although there were more NDS in higher fertilized varieties this was counterbalanced by a lower digestibility of NDF components.

The quality of straw studied in the two different experiments is compared in Table 8.

The three cultivars tested in two experiments (Table 8) indicate that the traditional (Hullubele) variety contains higher OM and OMD compared to hybrids. This was consistent in both trials which were conducted in the same year at different areas of the research station.

Table 8 Straw quality of three cultivars in 2 experiments

Constituents	Indaf-8		PR-202		Hullubele	
	Exp-I	Exp-II	Exp-I	Exp-II	Exp-I	Exp-II
Composition (% DM)						
Organic matter	87.5	88.2	89.1	89.2	90.5	90.5
NDF	65.0	66.1	67.5	67.0	67.0	67.0
In-vitro digestibility (%)						
Organic matter	61.5	59.7	58.4	58.7	62.8	61.0
NDF	48.1	45.9	45.7	46.2	49.6	47.4

Notes: Exp I Varieties harvested at different stages of maturity, (M-3 level) under effect of management
Exp II Effect of different levels of NPK on straw quality, (T-2 level)

CONCLUSIONS

The studies showed that variability of fingermillet straw quality and straw yield could be due to genotype, duration of growth, leaf content and level of fertilization. It seems possible that this variability could be used in plant breeding and in crop management to increase the quality and quantity of the straw harvested. Further research is, however, required to quantify the improvements in quality and quantity.

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NUTRITIVE VALUE OF STRAW, WITH SPECIAL REFERENCE TO WET-SEASON RICE STRAW AS RELATED TO VARIETY AND LOCATION OF GROWTH IN EAST-JAVA, INDONESIA

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SUMMARY

Variation in nutritive quality between morphological components is less for rice straw than for wheat straw. Wheat straw stems have a lower quality than stems of rice straw, while leaves and leaf sheaths of wheat are of better quality than of rice. Variation in voluntary organic matter intake, and in vivo *and* in sacco *organic matter digestibility was studied with straw of 10 rice varieties grown in two locations (highland and lowland) in two years in Indonesia. Variation in nutritive quality was observed between varieties. Variation in DOMI was higher than* in vivo *OMD.* In sacco *degradation parameters were poor predictors of* in vivo *OMD and DOMI. Grain yield of the rice varieties studied was positively correlated with DOMI.*

INTRODUCTION

Fibrous crop residues and agricultural by-products do play an essential role in the seasonal feed-plan of integrated smallholder crop-livestock farming systems in the tropics. The nutritive value of such low quality fibrous feeds for ruminants is affected by stage of maturity at harvest, the method of grain harvesting and the post harvest storage conditions. Variations in cutting height, growing conditions and harvesting and threshing procedures can result in large differences in the nature of leaf and stem material collected at the threshing site (Egan, 1987). Next to metabolizability and the efficiency of utilization of the absorbed nutrients, the nutritive value of fibrous feeds is largely determined by voluntary intake. Chemical characteristics are relatively poor predictors of the intake of digestible organic matter and thus of the fibrous feed's nutritive potential (Ørskov *et al.*, 1989). They found that in barley and wheat straws, whether or not treated with anhydrous ammonia, covering an *in vivo* digestibility range of 343-596 g/kg, *in vitro* digestibility and *in sacco* degradation characteristics were closely associated to feed intake and animal performance. After a comparison of wheat and rice straw, this paper discusses various aspects of the nutritive value of wet season rice straws with special reference to recent results obtained in Indonesia.

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CHARACTERISTICS OF WHEAT AND RICE STRAWS

The morphological variation of cereal straws varies considerably (Doyle *et al.*, 1987). As a proportion of the whole plant, excluding grain, wheat stem can range from 33% to 53% and rice stem from 22% to 34%. In addition to a genetically induced variation, it is obvious that these values are affected by harvesting height and growing conditions. Contrary to wheat straw (stem 24-36%, sheath 45-63% and leaf 58-77%), the variation *in vitro* organic matter digestibility (IVOMD) amongst plant parts showed to be less in rice straw (stem 43-75%, sheath 38-56% and leaf 45-60%). The grinding energy needed for physical reduction showed a comparable picture. Average values were 213, 122 and 81 J/g for wheat straw stem, sheath and leaf, respectively, whereas for rice straw values of 168, 147 and 133 J/g were reported. From these observations the conclusion seems valid that both physical and fermentative degradation of wheat straw stem is inferior to stems of rice straw, but that with sheaths and leaves the opposite seems the case. In rice straw stems, however, the energy needed for physical reduction remains high relative to its digestibility. Accordingly, relatively to OMD, eating rate of rice straw was lower as compared to wheat straw.

Time of harvesting may also significantly affect the straw's nutritive value. Pearce *et al.* (1988) clearly showed in wheat straw that initially after flowering the straw's neutral detergent solubles increased as caused by a production of photosynthates in excess of requirements for grain development. Thus the gradual decrease in OMD starting 20 - 30 days prior to flowering was temporarily equalized. However, a further decrease in OMD was observed soon after grain maturity, associated with a decrease in neutral detergent solubles. Thus in view of the straw's nutritive value, the timing of harvesting is presumably of an utmost importance, since the level of storage carbohydrates, fructans in wheat and starch in rice, retained in straw are critical to the straw's feeding value because of their high digestibility.

VOLUNTARY INTAKE OF WHEAT AND RICE STRAW

The intake of rice straw is influenced by various factors, amongst others by physical and chemical characteristics, palatability and degradability, differences in feeding conditions such as the amounts offered and the frequency and form of feeding, and finally the physiological state of the animal.

Whether with rice straw with a comparatively lower variation in digestibility between plant parts, selection for different plant parts plays a less important role as compared to wheat straw, is not quite clear. According to Doyle *et al.* (1987), for whole plant material, relatively to *in vivo* OMD, OMI, eating rate and IVOMD were lower with rice straw as compared to wheat straw.

The latter authors also pointed out that the intake of straw may be related to the previous nutritional history of the animals. Animals in good condition may be able to recycle more nutrients into the reticulo-rumen and thereby increasing microbial growth in the reticulo-rumen, and consequently intake.

NUTRITIVE VALUE OF RICE STRAWS IN INDONESIA

In East-Java, 10 rice varieties (Table 1) were planted at two locations: Mojosari (lowland, regosol, 28 m above sea level) and Malang (highland, alluvial soil, 435 m above sea level). First transplanting (I) was done in early March 1988 in the wet season. Harvesting was in May-June at the onset of the dry season. This wet-season planting (II) was repeated in 1989. Intake and *in vivo* digestibility of the rice straws were tested with young fat-tailed sheep with a body weight of 20 - 25 kg. Rice straw was

Table 1 *In vivo* organic matter digestibility (g/kg) of 10 rice straw varieties, grown at 2 locations (lowland: Mojosari; highland: Malang) in the wet season of 1988 and 1989

Variety	Mojosari		Malang		Mean[1]
	1988	1989	1988	1989	
A. IR 36	461	476	390	463	448
B. Batang Pane	457	495	471	471	474
C. IR 54	414	471	422	398	426
D. IR 64	457	486	457	440	460
E. Citandui	454	468	422	454	450
F. Progo	483	449	486	477	474
G. Cisadane	367	514	469	525	469
H. Krueng Aceh	473	458	531	497	490
I. Kapuas	464	502	487	530	496
J. Tuntang	468	529	468	489	489
Mean[2]	450	485	460	474	468

Note: - least significant differences (LSD), $P < 0.05$: 1) 46.2; 2) 29.2

Table 2 Voluntary intake of digestible organic matter (g/kg MW) of 10 rice straw varieties, grown at 2 locations (lowland: Mojosari; highland: Malang) in the wet season of 1988 and 1989

Variety	Mojosari		Malang		Mean[1]
	1988	1989	1988	1989	
A. IR 36	18.0	17.2	10.4	17.1	15.7
B. Batang Pane	18.3	18.1	16.5	18.8	17.9
C. IR 54	11.5	15.7	13.8	13.2	13.6
D. IR 64	11.8	17.7	12.2	16.5	14.6
E. Citandui	14.8	16.1	13.9	15.6	15.1
F. Progo	13.5	15.3	16.9	18.3	16.0
G. Cisadane	12.7	18.6	13.7	18.0	15.8
H. Krueng Aceh	19.2	14.8	17.5	16.0	16.9
I. Kapuas	16.5	19.1	18.9	22.8	19.3
J. Tuntang	16.1	20.5	18.8	21.5	19.2
Mean[2]	15.2	17.3	15.3	17.8	16.5

Note: - least significant differences (LSD), $P < 0.05$: 1) 2.96; 2) 1.87

offered at a level of 10 - 20 % excess and was supplemented with about 18 g DM/kg MW of concentrates containing about 20 % crude protein. The season I *in vivo* digestibility trials were run in the period December 1988 till June 1989; of the season II rice straws in the period December 1989 till April 1990. Tables 1 and 2 show the rice straw's organic matter digestibility (OMD) and voluntary intake of digestible organic matter (DOMI), respectively.

Voluntary intake of rice straw OM was slightly positively related to the straw's OMD ($R^2 = 0.16$, $P < 0.01$). Hence the variation in DOMI with a coefficient variation (CV) of 17.2 % exceeded that of OMD (CV = 8.1 %).

DIGESTIBILITY OF RICE STRAW

The *in vivo* digestibility of rice straw is highly variable. In such highly fibrous material only a minor part of the OM is water soluble. In addition to this it seems that the fractional rate of passage of the liquid phase from the reticulo-rumen is low. A pilot experiment with sheep fed on urea- ammonia treated rice straw as a basal feed in Indonesia revealed 6.1 %/h for the liquid phase (Co-EDTA). Hence digestion occurs almost quantitatively by fermentation, predominantly in the reticulo-rumen. A minor part, generally less than 10% of the fermentation products emerge from the hind gut. Digestion in the small intestine is almost limited to the microbial biomass synthesized in the reticulo-rumen, of which the true protein digestibility approximates 85% (Storm *et al.*, 1983; Van Bruchem *et al.*, 1989).

The extent to which the feed is degraded in the reticulo-rumen depends on its water soluble part, which presumably is degraded almost quantitatively by the rumen microbes, and the water insoluble part. This water insoluble part in turn can be divided into a part which is truly resistent to microbial degradation and a potentially degradable part. Of the latter part the extent of degradation is related to a lag phase related to rate of attachment of the microbes as well as subsequently the rate of colonization, the *in situ* fractional rate of degradation and the residence time in the reticulo-rumen. In turn the residence time is determined by the rate of physical degradation of large into small particles and the subsequent passage of the latter to the omasum.

In temperate cereal straws a close relationship was found between *in sacco* OM degradation characteristics and *in vivo* digestibility. These biological measures were found to be superior to chemical analyses. This can easily be understood based on the above theoretical considerations. However, in rice straw the picture thus far obtained is less clear. In Table 3, the rice straw's *in sacco* degradation characteristics, determined in sheep according to Mehrez and Ørskov (1977), are presented.

The multiple regression of IDOM versus S, D, t′ and kd gave results as presented in Table 4.

Table 3 Effect of variety and location of growth (lowland, L; highland, H) on *in sacco* OM degradation of wet-season rice straw (mean of seasons I and II)

Variety	S[1]		D[2]		R[3]		t′[4]		kd[5]	
	L	H	L	H	L	H	L	H	L	H
A. IR 36	189	186	481	408	330	406	5.5	8.1	2.7	3.3
B. Batang Pane	210	168	463	416	328	417	6.1	5.7	3.1	3.0
C. IR 54	200	163	401	363	399	474	6.5	7.0	2.7	2.4
D. IR 64	198	162	378	381	424	457	6.3	5.5	3.3	3.1
E. Citandui	177	180	402	290	422	530	6.5	6.5	3.1	3.4
F. Progo	192	163	405	345	403	493	5.2	6.0	3.1	3.1
G. Cisadane	200	157	380	390	420	453	6.4	6.0	3.0	2.4
H. Krueng Aceh	215	178	400	437	385	386	6.2	4.7	3.7	3.0
I. Kapuas	208	183	425	439	367	379	5.8	6.6	2.9	3.3
J. Tuntang	186	195	487	378	327	427	4.2	7.6	2.8	3.0
Mean	198	173	422	385	380	442	5.9	6.4	3.0	3.0

Notes:
1) S: water soluble part (g/kg), estimated as (a) in the exponential equation: $a + b * (1 - \exp(-c * (t-t')))$; least significant difference (LSD, $P < 0.05$) 9.6
2) D: water insoluble but potentially degradable part (g/kg), estimated as (b); LSD ($P < 0.05$) 14.1
3) R: truly undegradable part (g/kg), equivalent to 1000 - (a + b); LSD ($P < 0.05$) 7.6
4) t′: lag phase (h); LSD ($P < 0.05$) 3.29
5) kd: fractional rate of degradation of D, estimated as c (%/h); LSD ($P < 0.05$) 1.38

Figure 1 Observed DOMI values versus DOMI values fitted from the multiple regression analysis vs. S, D, t′ and kd

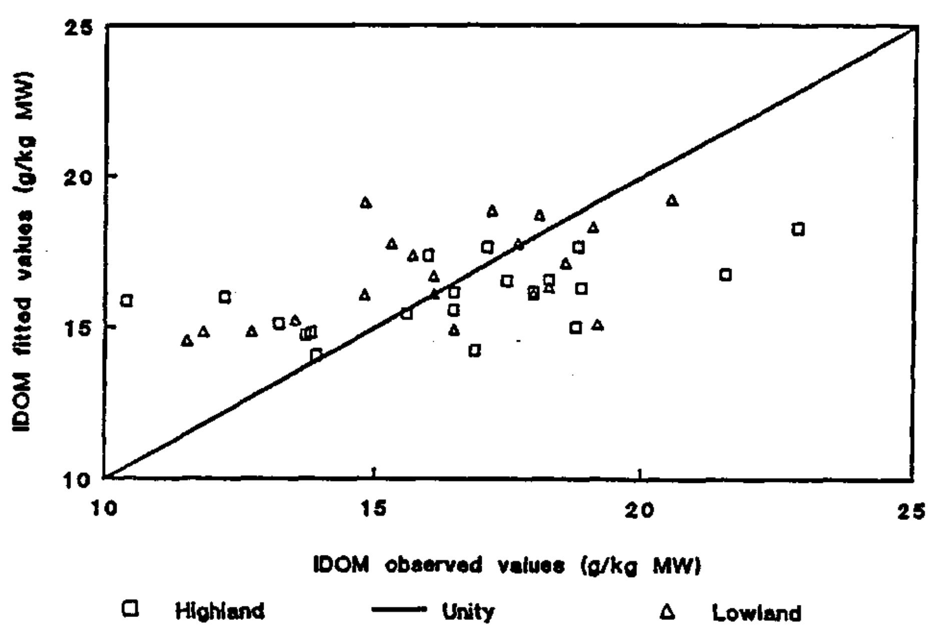
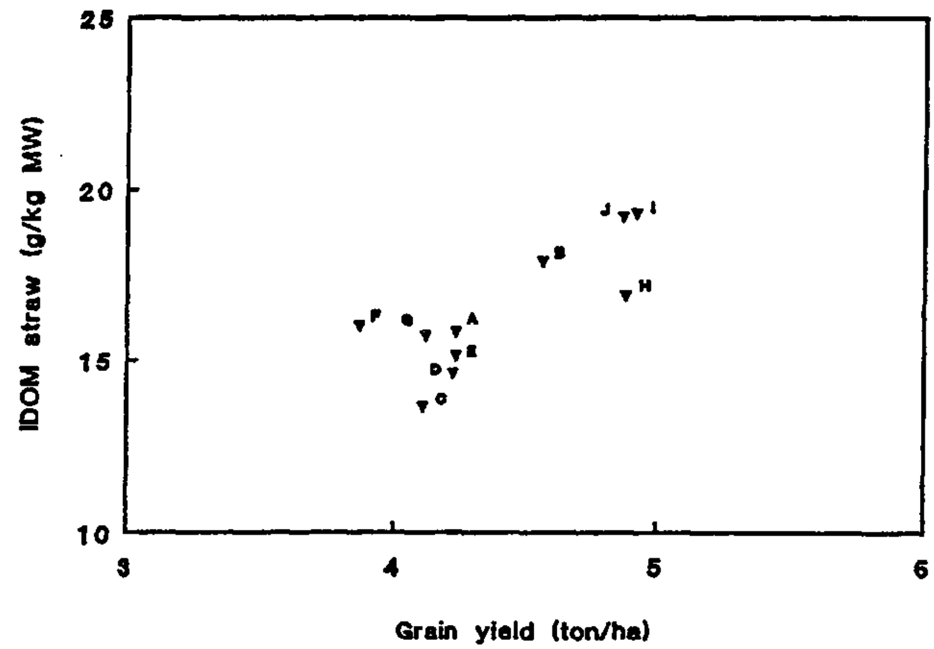


Table 4 Prediction of DOMI from OM *in sacco* degradation characteristics

Factors	Equations	R2
S	20.1 - 0.20*S	0.072
D	8.6 + 0.19*D	0.211
S + D	10.1 - 0.05*S + 0.18*D	0.215
t'	16.9 - 0.09*t'	0.002
S + D + t'	9.3 - 0.05*S + 0.19*D + 0.09*t'	0.217
kd	12.1 + 1.44*kd	0.084
S + D + t' + kd	5.7 + 0.01*S + 0.18*D - 0.03*t' + 1.16*kd	0.262

Figure 2 Nutritive value (DOMI) of rice straw as related to grain yield. Mean of two wet-season crops and two attitudes (letters indicate varieties, see Table 1)



In Figure 1, the fitted DOMI values as derived from this multiple regression analysis are plotted versus the observed DOMI values, showing a somewhat less clear cut relationship as compared to the temperate cereal straws (Ørskov *et al.*, 1989). In line with the differences in truly undegradable OM residue (R) between lowland and highland (see Table 3), 48-h OMD was lowest for highland rice straws. Somewhat surprisingly, this difference was not reflected in the *in vivo* OMD (see Table 1).

It thus seems that further research is needed to elucidate why in rice straw the *in sacco* OM degradation characteristics are such poor predictors of *in vivo* OM digestibility. Since the rice straws were offered in excess, perhaps part of this absent relationship could be explained by selection. Generally, however, the rice straw residues did not exceed 20% of the quantity supplied, so that these residues can hardly be expected to account for this. It would also be possible that due to differences in physical characteristics the rates of physical degradation of large into small particles differ. Finally, the rate of passage to the omasum may differ, due to the consistency of the reticulo-ruminal contents and the shape and/or functional specific gravity of the small particles. Possibly, in experiments with Cr-mordanted rice straw particles such differences could be identified.

RELATION BETWEEN GRAIN YIELD AND STRAW QUALITY

Identifying the most suitable rice variety is first of all related to its grain yield. The straw's quantity and quality have to be regarded as a second priority. This is elaborated in this workshop in the paper by De Wit *et al.* (1993). Hence, it is worthwhile to investigate the relation between straw quality, straw quantity and grain yield. Figure 2 is a pictorial presentation of this relationship as derived from the data obtained in Indonesia, showing that as averaged over both altitudes and seasons the straw's nutritive value fortunately seemed positively related to grain yield. This possibly could be explained on the basis of a variation in photosynthetic capacity, and the fact that harvesting took place at a stage that the straw was still greenish, and the excess of photosynthates produced were as yet not completely stored in the grain. These observations are not in line with those of Erickson *et al.* (1982), who observed in barley a poor relationship between grain yield and straw quality.

CONCLUSIONS

Significant differences between *in vivo* OMD, DOMI and *in sacco* degradation parameters were found for straw from 10 rice varieties grown in Indonesia. Variation in DOMI was higher for DOMI than for *in vivo* OMD. *In sacco* degradation characteristics could only explain 26.2% of variation in DOMI. No significant effects of location of growth (highland or lowland) on *in vivo* determined quality parameters were found, but *in sacco* degradability was significantly better for straw of rice cultivated in highland than for rice grown in lowland. A positive relation was observed between grain yield and DOMI for the ten rice varieties studied.

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EXPLOITATION OF GENETIC VARIABILITY
FOR IMPROVED NUTRITIVE VALUE OF CEREAL STRAWS

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SUMMARY

Considerable variability has been found in digestibility and intake of different varieties of cereal straws. Nowadays it is asked whether parameters as digestibility or other nutritive characteristics may be included in the breeding programs of plant breeders, so that digestibility of the straw may be improved without affecting the grain yields. This paper presents chemical composition and digestibility of whole plant and plant parts in rice and wheat varieties. A total of 21 varieties of rice straw showed that nylon bag organic matter digestibility (NBOMD) ranged from 44.3 to 54.7%, neutral detergent fibre (NDF) from 650 to 770 g/kg DM, and crude protein (CP) from 30 to 63 g/kg DM. NDF and CP-contents were found to affect NBOMD positively in rice and wheat varieties. NBNDFD correlated positively with NBOMD. The NBOMD of leaf was highest and that of internode lowest for rice. The NBDMD and OMD of 10 parents and their 15 F1's indicated higher digestibility in F1. The F1 were also found to contain higher CP-contents than their parents. An in vivo trial indicated a difference of 8 units in the in vivo OMD of two varieties.

INTRODUCTION

Wheat and rice straws are low in protein, vitamins, minerals and digestible energy, resulting in low digestible organic matter intake (DOMI) and low animal production. Many efforts in India and abroad have been made to overcome the problems of low digestibility and/or intake of such residues by treatments or supplementation. Most of the techniques developed so far have not been adopted by farmers due to practical reasons (Mahendra Singh, 1993; Saadullah and Siriwardene, 1993) or because the economics of urea treatment are not favourable under many circumstances. However, the use of these crop residues for feeding of livestock remains important in small holder crop and livestock mixed farming systems as practised in developing countries (McDowell, 1986). The economic value of straw may exceed that of grain in some circumstances especially in areas of uncertain rainfall (Nordblom, 1983; De Wit *et al.*, 1993). Work with some cereals indicates that grain yield is not necessarily negatively correlated with straw digestibility (White *et al.*, 1981; Capper, 1988) and a positive relationship may occur (Bainton *et al.*, 1986). Hence, it may be possible to select varieties for higher digestibility. Sometimes doubts are expressed that selection for shorter, stiffer stemmed and presumably more lignified straw may cause low feeding value. However, the results obtained are

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contrary to this (Capper *et al.*, 1986) as dwarf and semi-dwarf varieties have higher proportion of leaf to stem in comparison to tall varieties (Randhawa, 1988). Rice breeders feel that the presence of genetic linkages has limited the potential of true breeding lines which were developed in the conventional breeding programs. It is in this respect that F1 hybrids should enable us to break these linkages while retaining the desirable ones. This is evidenced by spectacular advances made in China in development and cultivation of F1 rice hybrids which have out-yielded the best available conventionally bred non-hybrid varieties by 20 - 30% (Yuan, 1977; Lin and Yuan, 1988). Results of Virmani *et al.* (1981 and 1982) also indicated that significant heterosis exists in rice which can be exploited to develop high yielding rice varieties using cytoplasmic male sterility and fertility relationship systems. Keeping all this in view, this paper highlights varietal factors that contribute to higher nutritive value and the possibility of improving the nutritive value of straw through breeding.

CHEMICAL COMPOSITION AND DIGESTIBILITY

Rice straw

Twenty-four straws were used from 21 varieties (see Table 1), of which twelve were grown in an agronomic trial during 1988 and twelve in a plant breeding trial of 1989. Three varieties occured in both the agronomic and plant breeding trials in both years.

All varieties were hand harvested at 6 - 7 cm above ground and their chemical composition and nylon bag organic matter digestibility (NBOMD) were determined. On the basis of NBOMD they were divided into three groups A, B and C with high, medium and low digestibility, respectively (Table 2).

The NBOMD after 72 hour incubation varied from 443 to 548 g/kg with an average of 530, 501 and 453 in A, B and C respectively. Chemical composition between B and C was similar so the difference of NBOMD between B and C may be due to faster rate of degradation of neutral detergent fibre (NDF) in B. However, the difference between A and B can be due to (a combination of) higher neutral detergent solubles (NDS), higher crude protein (CP) and lower cell wall contents for A. Straws with higher NDS content have a tendency to show lower NDF digestibility (NDFD) (Prins, 1987). The overall higher NBOMD in A was attributed to the higher NDF ($r = 0.9$) and cellulose digestibility ($r = 0.7$). Of the varieties, Saket-4, Pantdhan-4 and Sita were used in both the agronomic and plant breeding trials. They repeated their performance in respect of NBOMD, which indicates the absence of a year effect on ranking. In both years varieties were grown in the same soil and site using similar agronomic practices.
The NBOMD was positively correlated ($r = 0.66$) with CP of the

Table 1 Rice varieties used in the trial, grouped according to quality

Group A	Group B	Group C
Saket-4 (2)	Narendra-2	Sita (2)
IET-8580	Pantdhan-4 (2)	VL-8
Narendra-118	Ratna	IET-9362
Pantdhan-6	Sarju-52	
UPR-79-123	IR-8	
Manhar	IR-24	
Jaya	VPR-83-34	
	IET-8111	
	IET-8110	
	UPR-80-120	
	Govind	

Note: for the reasons of this grouping see text and Table 2

Table 2. Chemical composition (g/kg DM) and digestibility of nutrients (g/kg DM) in rice straws

Nutrients	Groups		
	A high NBOMD	B medium NBOMD	C low NBOMD
Chemical composition:			
NDF Av.	692	729	728
Range	653 - 733	697 - 745	700 - 769
Hemicellulose Av.	231	251	250
Range	208 - 254	233 - 288	226 - 275
Cellulose Av.	298	324	309
Range	242 - 345	285 - 368	281 - 328
Crude Protein Av.	54	48	46
Range	35 - 63	30 - 62	37 - 52
Digestibility			
Org. matter Av.	530	501	453
Range	518 - 548	480 - 512	443 - 465
Hemicellulose Av.	515	522	448
Range	462 - 600	477 - 575	362 - 517
Cellulose Av.	482	480	420
Range	458 - 507	439 - 522	386 - 460
NDF Av.	457	439	390
Range	429 - 477	411 - 455	375 - 407

straw, with an increase of 39 g/kg in NBOMD was observed for every 10 g/kg increase in CP, which might be specific for nylon bag measurements. The CP contents of Basmati, Jaya and Sita were 40, 55 and 36 g/kg and their NBOMD, were 540, 450 and 430 g/kg and NBDMDS were 601, 568 and 587. Varieties with lower NDF contained more CP. Thus part of the CP seems to be component of NDS which strengthens the positive correlation between CP and NBOMD.

Wheat straw

Straws of six wheat varieties each with four field replications grown under uniform agronomic conditions in a plant breeding trial were collected and analysed for chemical composition and digestibility (see Table 3).

Table 3 Chemical composition (g/kg DM) and nylon bag digestibility (g/kg DM) of different varieties of wheat straws

Nutrients	Raj3077	HD2329	HD2428	Raj 1972	PBW154	WL711	Average
Chemical composition:							
NDF	791^{d}	781^{d}	703^{a}	758^{c}	732^{b}	754^{c}	754
SD±	11.8	12.4	5.8	3.2	13.5	8.5	3.8
ADF	519^{d}	510^{d}	453^{a}	470^{ab}	479^{b}	492^{cd}	487
SD±	18.6	9.1	6.7	10.7	15.1	11.7	27.6
Hemicellulose	273^{cb}	270^{cb}	243^{a}	281^{c}	253^{ab}	62^{ab}	265
SD±	21.3	12.3	17.2	8.4	2.0	12.2	14.2
Cellulose	412^{d}	403^{d}	333^{a}	367^{e}	366^{de}	386^{c}	378
SD±	13.5	12.7	10.3	8.0	7.1	7.8	26.2
Crude Protein	30^{ab}	29^{a}	33^{b}	39^{e}	38^{de}	35^{c}	34
SD±	0.6	0.4	0.5	0.3	0.8	0.7	0.4
Digestibility							
Org. matter	483^{a}	503^{b}	512^{b}	520^{cb}	547^{cd}	571^{d}	523
SD±	37.5	49.8	24.8	29.5	22.5	18.3	22.4
NDF	468^{b}	490^{b}	427^{a}	482^{b}	506^{bc}	532^{c}	484
SD±	42.8	46.1	36.1	28.7	34.9	20.4	31.2
ADF	426^{a}	477^{b}	386^{a}	413^{a}	468^{b}	505^{b}	446
SD±	44.2	50.4	53.0	40.4	37.2	34.6	45.4
Hemicellulose	543^{b}	513^{a}	517^{a}	600^{c}	523^{b}	580^{bc}	546
SD±	24.6	65.9	51.1	50.1	63.4	23.4	28.7
Cellulose	441^{b}	474^{cd}	362^{a}	390^{ab}	455^{c}	524^{d}	441
SD±	61.3	69.2	64.9	56.3	34.2	27.9	48.4

Source: Nazim Ali (1991)
Notes: Figures bearing different superscripts are different statistically ($P < 0.01$)

The data in Table 3 indicate that Raj 1972, PBW-154 and WL-711 had similar chemical composition with different NBOMD. The higher digestibility in these varieties might be contributed to an increased rate of degradation of NDF, ADF and cellulose in comparison to the others. WL-711 and Raj 3077 belong to two different genetical lines. The digestibility of Raj 3077 and HD 2329 was low because of their higher NDF and lower CP contents. However, in variety 2428 the NDF was less digestible. Perhaps, the varieties differed in proportions of leaf and stem, as NDF from leaf is more digestible than that of stem because they are composed of different cell types.

It may be concluded that NDS in rice and wheat straws was positively correlated with NBOMD and NDF of certain varieties were more digestible resulting in the observed variation of NBOMD in cereal straws.

CHEMICAL COMPOSITION AND DIGESTIBILITY OF PLANT PARTS AND EFFECT OF NITROGEN FERTILIZATION

Straws of several rice varieties were grown at 40 and 120 kg N/hectare in an agronomic trial, and harvested 5 - 6 cm above ground level, threshed and separated into different parts. The chemical composition and NBOMD (72 hour incubation in nylon bags) was determined (see Table 4). Internodes contained more ADF and cellulose than leaves. N fertilization did not affect chemical composition or digestibility.

Table 4 Chemical composition (g/kg DM) and digestibility (g/kg) of different parts in rice straw at two levels of N application

Nutrients	Node		Internode		Leaf blade		Whole plant	
	40	120	40	120	40	120	40	120
Chemical composition								
Crude protein	42	54	46	43	32	32	37	39
ADF	459	467	508	522	478	478	475	477
Cellulose	337	332	375	382	280	282	295	304
Digestibility								
Org. matter	495	503	418	436	584	598	501	505
NDF	428	427	398	384	522	518	430	446
ADF	380	391	364	332	493	478	400	402

Source: Atharuddin (1989)

The leaf blade had higher NBOMD and NBNDFD than nodes and internodes. Winugroho (1981) showed an opposite trend to this for rice straws, but in wheat straws he found similar results to ours i.e. leaf blades were more digestible than internodes. The differences between his and our data might be due to different genotypes or different environmental conditions. For example, paddy plants grown under long standing water in damp soils may show higher digestibility of stem than plants grown under dry conditions. This needs further testing.

HETEROSIS IN CHEMICAL COMPOSITION AND DIGESTIBILITY IN RICE

The straws of 15 F1 crosses with their 10 parents were collected from one rice breeding experiment. Their chemical composition and DMD (72 hour incubation in nylon bag) is shown in Table 5.

Crossing of two varieties always resulted in a hybrid of higher NBDMD then the parents except in the case of Narendra-118 crossed with Pantdhan-6. Elimination of the cross with negative heterosis (Narendra-118*, Pantdhan-6) from heritability (h^2) estimation by regression (Falconer, 1960) gave h^2 values of 0.86 and 0.82 for NBDMD and NBOMD respectively (Gupta, 1991). As can be seen from Table 1 both Narendra-118 and Pantdhan-6 fall already in the better group, i.e. little additional improvement in their cross can be expected. In most hybrids, the CP content also improved, either over both or one of the parents. An exception occurs for a cross produced from Narendra-118 and Pantdhan-6. Both these varieties fall under group 'A' in Table 2, but belong to two different genetic lines. It seems the CP content is controlled by polygenes whose combination seems to be identical in these two varieties. Genes become segregated upon crossing and are thus responsible for a lower CP which had shown a positive correlation with digestibility. Positive correlation between CP and digestibility with simultaneous reduction in NDF of hybrids are desirable characteristics of the straws in order to improve nutritive value. A higher NDF can however be compensated by a higher digestibility. Deinum (1988) suggests that CP correlates negatively with grain yield when a (maize) crop is grown under good conditions. Hybrids are known to give better grain and higher CP in straw and lower crude fibre and total ash (Devasia *et al.*, 1976). In paddy varieties nowadays, emphasis of plant breeding is to cultivate hybrids as is being done in China. This may have better effect on nutritive value as suggested in the data in Table 5. However, these aspects need more studies to ensure that these effects are repeatable and can be translated into higher intakes and/or *in vivo* digestibility. Relation between this and total biomass or grain yield also need to be studied.

Table 5 Chemical composition (%) and NBDMD digestibility (%) of parents and hybrids in rice straw of different varieties

	Parents			Hybrids			
	CP	NDF	NBDMD	CP	NDF	NBDMD	NBOMD
IR-58*	4.2	70.1	47.1	-	-	-	-
UPR-85-32	3.5	73.7	42.0	4.9	65.2	51.7	52.9[b]
IET 7566	4.6	66.4	46.3	4.9	69.5	49.9	51.0[ab]
IET 7613	4.7	68.6	49.9	5.4	68.2	54.6	55.7[c]
UPR-83-169	5.1	66.2	49.0	6.5	65.8	54.5	55.6[c]
UPRH-39	5.6	71.3	46.9	5.4	67.3	50.2	51.4[ab]
Pantdhan-6	5.3	69.8	49.3	5.8	67.6	53.8	54.8[c]
Narendra-118*	5.1	69.2	48.0	-	-	-	-
UPR-82-43	3.6	72.1	41.2	5.3	66.9	49.8	51.1[ab]
UPR-85-32	3.5	73.7	42.0	6.0	67.7	50.7	51.8[b]
IET 7566	4.6	66.4	46.3	6.5	66.5	52.2	53.4[bc]
IET 7613	4.7	68.6	45.9	6.1	70.6	52.0	53.0[bc]
Pantdhan-6	5.3	69.8	49.3	4.7	68.1	47.9	49.0[a]
IET 6223*	4.4	66.6	45.1	-	-	-	-
IET 7566	4.6	66.4	46.3	5.3	66.7	51.2	52.3[b]
IET 7613	4.7	68.4	45.9	5.7	64.6	50.1	51.2[ab]
UPRH-39	5.6	71.3	46.9	5.4	68.5	49.7	50.9[ab]
Pantdhan-6	5.3	69.8	49.3	6.0	69.0	52.2	53.4[bc]
Average of all	4.7	69.4	47.9	5.6	67.5	51.4	52.5

Source: Gupta (1991)
Note: * within group 1 IR-58, group 2 Narendra-118 and group 3 IET 6223 were crossed with the varieties listed below then to produce hybrids

IN VIVO DIGESTIBILITY OF STRAWS OF RICE VARIETIES

Three varieties, Sita, Jaya and Basmati from different fields were handcut at 7-8 cm from ground level and threshed in a standing combine and chopped with a hand operated chopping machine. Ten Sahiwal and two cross-bred male growing calves in age group of 8 - 12 months weighing between 69 and 113 kg were divided into four groups of 3 animals each on the basis of their body weight and age and alloted to one of the straws randomly. Depending on the consumption, 4 - 5 kg straw was offered to each animal daily. Total feeding period lasted 15 days, with a preliminary period of 10 days with 5 days digestion trial. *In vivo* DMD and DMI data are given in Table 6. Basmati had a higher DMD and a lower DMI in comparison to Jaya and Sita by about 8% units, resulting in similar DDMI per $kg^{0.75}$. The reasons for the differences between the intake and digestibility of these straws was not determined and indicates the need for more controlled studies to identify the reasons for differences in nutritive value between straws.

Table 6 *In vivo* DMD and intake of rice varieties

Nutrient	Varieties		
	Basmati	Jaya	Sita
Number of animals	4	4	4
Average body weight (kg)	86	80	87
DMI (kg/day)	1.8	2.2	2.5
DMI (kg/100 kg BW)	2.1	2.8	2.8
DMI ($g/kg^{0.75}$)	65	84	86
DMD (%)	44.5	35.9	36.6
OMD (%)	54.2	44.7	43.2
NBOMD (%)	60.12	56.82	58.66
DDMI (kg/day)	0.81	0.80	0.90
DDMI ($g/kg^{0.75}$)	29	30	32
DOM1 (kg/day)	0.90	0.76	0.85
DOM1 ($g/kg^{0.75}$)	37	29	29

CONCLUSIONS

The digestibility in cereal straws varies among and between the cultivars. The differences are mainly because of variation in morphological characteristics of the different varieties which in turn are controlled by the genetic make up and growing conditions. Different varieties tested in this study were grown under similar environment and locations and they even repeated their performance over years. It indicates that the variation in the digestibility is at least partly caused by the genetic background of the variety. A variety like UPR-79-123 is recently produced by Pantnagar University from the IR-36 genetic line and considered for release. It has a relatively high straw digestibility and grain yield and is a good example of the possibility to improve the nutritive value of straws through breeding. The cultivation of hybrids in rice may also help in production of straw of higher nutritive value. Further work is required to study repeatability of relative contribution of genetic and environmental effect.

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RELEVANCE OF BREEDING AND MANAGEMENT FOR MORE OR BETTER STRAW IN DIFFERENT FARMING SYSTEMS

J. De Wit[1], J.P. Dhaka[2] and A. Subba Rao[3]

SUMMARY

Straw is becoming more important for ruminant feeding, although its relative importance differs per grain species. Breeding and/or management for better or more straw does not necessarily affect grain yield and therefore breeding or management for straw quality and quantity (the socalled "variability work") is highly relevant. This paper discusses relative importance of various straw characteristics, for different types of grain species, production goals and production circumstances. The variability work in India seems to be especially relevant for sorghum and millets because of the relatively low grain/straw price ratios. In these cases it is attractive to increase straw quantity. Increased straw quality is a priority when the objective is high milk production and when supplements are hardly available or expensive. Straw quantity is relevant where good quality supplementary fodder/feed is available and/or maintenance of animals is more important than high levels of milk production. Furthermore it is concluded that loss of quality during storage deserves priority attention.

INTRODUCTION

Straw is becoming more and more valuable as animal feed. Some reasons for this are:
- reduction of common grazing land availability (Jodha, 1986);
- increased income for some people results in a relatively higher demand for animal products compared to staple food due to differences in price elasticity (Kelley *et al.*, 1991).

The straw can be utilized in different manners:
- after grain harvest both straw and stubble can be fed or grazed;
- stripping or grazed immmature leaves before grain harvest (Khazaal *et al.*, 1991; Osafo *et al.*, 1991);
- dense planting of coarse grains with subsequent thinning until ripening of the crop (Byerlee *et al.*, 1989);
- grazing of a failed harvest or as a winter crop (Nordblom and Ceccarelli pers. comm.) with interesting work on optimization of harvest stage by Nordblom (1983);
- cutting of a green crop before flowering, as is done with winterwheat or oats but also in rice systems where the season

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is too long for one crop and too short for two crops (Robles *et al.*, 1991).

This paper discusses the choice between the need for quantity and/or quality of straw, assuming that grain yield remains unaffected by these choices. We also assume that "straw" is not used for fencing, roofing, fuel or other purposes.

BREEDING OR MANAGEMENT FOR MORE OR BETTER STRAW

Straw quantity and quality can be increased without necessarily a major negative effect on grain production (Badve *et al.*, 1993; Capper *et al.*, 1989). Therefore the emphasis of plant breeders on grain yields alone, with neglect of straw quality and quantity, is increasingly criticised. Kelley *et al.* (1991) indicate that in some cases breeding programs on grain sorghum had resulted even in a negative impact on total value of production (being the sum of straw and grain value). The general conclusion is that straw quality and quantity characteristics should be considered in the plant breeding or management programs. In fact, the low straw quality or quantity of modern cultivars is sometimes a reason for the non-adoption of the "grain" variety (Seetharam pers. comm., 1991). Decreased straw quality has been reported to be reflected in a 30 - 40% lower price for these straws (Kelley *et al.*, 1991).

Other papers in this workshop have shown that the development of research priorities and extension messages in the diversity of India requires definition of specific farming systems to provide specific answers (Jain and Dhaka, 1993; Patel *et al.*, 1993). The relative importance of straw quantity, straw quality or grain production in different circumstances (farming systems) is the central item of this paper. This question of quality versus quantity is important for breeding and management of crop (residues), but also an essential feature in optimizing feed production in general. See for example Belton and Michell (1989) for an analysis referring to fodder conservation and Zemmelink *et al.* (1992) for fodder selection in general. The issue will be dealt with by discussing differences in straw/grain price ratios, production goals and production circumstances.

FARMING SYSTEMS

To analyse the effect of differences in agro-ecological circumstances on the relative importance of straw characteristics, a linear programming (LP) study was carried out for 3 hypothetical farming systems that reflect distinct but existing conditions in India (see Table 1). Assumptions are listed in Box 1.

Table 1 Description of three simplified farming systems used for the model

	Karnataka	West-Bengal	Haryana/Punjab
Crops/year	1[1]	2[1]	2[1]
Irrigation	-	+	++
Major grains cultivated	fingermillet	rice	rice/wheat
Common grazing land availability	++	+/-	-
Ratoon (grazing)	300 kg/ha/year[1] (50% TDN, 10% CP)	0[1]	0[1]
Green fodder availability	0[1]	0[1]	2 crops/year, 20% of crop area[1] (8000 kg DM/ha, 70% TDN, 20% CP)
Relative animal density	++	+++	+
Production objective	draught/milk	draught/milk	milk/calves

Note: [1] - assumptions used in LP-model

Box 1 Assumptions for the calculations of the model

The following assumptions are made to make a simplified estimate of the potential animal production per hectare:

- animal requirements are according to NRC (1988).
- DMI depends on quality of feed and production level of the animal and is predicted by the following equation (derived from Tolkamp and Ketelaars, 1992):

  DMI = 1.3 * a * (-19.5 + 0.05979 * CP(om) + 92.46 * TDN/1.2148) * 1.05/TDN

  where:

  a = factor depending on level of production: 1.5 - 1.8 for 0 - 12 kg milk / day

  DMI = g / $kg^{0.75}$;

  CP(om) = g CP/kg organic matter.

  For the (low) levels of animal production, which are the most relevant for management of straw, the predicted DMI is similar to the predictions that Joshi et al. (1993) have made.
- nutritive values for straw and bran are 45% TDN and 4% CP resp. 60% TDN and 12% CP;
- grain : straw : bran = 1 : 1 : 0.1; no concentrate is bought from outside. Grain production is 3000 kg/ha per season;
- bran is allowed to constitute not more than 60% of the total ration;
- storage losses of 1.5% in quantity and 0.75% of TDN in quality per month are included;
- the LP-model was allowed to choose between different types of cows (milkproduction ranging from 0 - 12 kg/day), but total number of cows was to remain equal over the different seasons only cows and no followers are considered;
- no supplementary feeds (either grass from common land or concentrates) from outside the farm are included;
- the matrix used is very similar to the one used by Patil et al. (1993). Details can be obtained from the authors.

RESULTS

A comparison of the absolute level of milk production and the type of cow which the LP-model chooses for the three situations, is not so interesting. Because of the large amount of good quality fodder available in Haryana/Punjab, total potential production per hectare and per cow is considerably higher (Table 2). A comparison of the limiting factors is more interesting and shows that straw quality is the major limiting factor in all three situations. Straw availability (= quantity) becomes a major limiting factor when good quality fodder is available (Haryana/Punjab), though straw quality (= TDN value) still has a larger impact than quantity.

CP-content appears to be the most important limiting factor in West-Bengal, and to a lesser extent also in Karnataka. However breeding for CP-content is not advisable. Firstly, the CP-content of straw relates negatively with grain yield (Deinum, 1988), and secondly, because CP-deficiencies can easily be overcome by the addition of small quantities of protein-rich supplement or urea. If, for example, the CP-content of the straw was increased in the model only slightly from 4 to 5%, then TDN becomes the major limiting factor, more than straw availability. The important relations between CP and TDN are further elaborated by Walli *et al.* (1993)

An increase or decrease of nutritive values affects the results considerably (see Table 2). This underlines both the need for careful interpretation, but also the sensitivity of the system to small changes in quality and quantity of straw, obtained through breeding or management.

Table 2 Changes in potential milk yield (kg/ha/day) by changing different constraints for the hypothetical situations

	Karnataka	West Bengal	Haryana/Punjab
Total milkprod (kg/ha/d)	1.54	1.79	19.00
Straw availability			
-10%[1]	0	0	-1.5%
+10%[1]	0	0	1.5%
CP-content of straw			
-10%[1]	-4.2%	-3.4%	-1.0%
+10%[1]	6.2%	5.6%	1.0%
TDN-content of straw			
-10%[1]	-18.5%	0	-9.7%
+10%[1]	0.9%	0	6.9%
Storage losses			
Double of original (%)	-1.5%	-1.3%	-5.6%

Note: [1] - % of original value (see assumptions)

It is relevant to note that chopping of straw is practiced mainly in those farming systems where the model indicates the importance of straw quantity (= relative shortage of straw). Leaving aside the differences in straw type (coarse vs. slender), it can be observed that chopping is mainly practised in areas where supplementary feed is available (e.g. berseem in Haryana/Punjab), or other situations where straw quantity is the most important factor (drought prone areas or areas whith relatively high animal densities). Chopping reduces the waste due to refusal (quantity!), while selective consumption (when no chopping is practised) results in an increased quantity and quality of the ingested feed, thereby increasing the production per animal (Zemmelink, 1980; Prabhu *et al.*, 1988; Wahed *et al.*, 1990).

The importance of storage losses as a limiting factor to animal production is another point revealed by the model-study, because even marginal losses as assumed in the model resulted in a considerable decrease in milk production. This will be worse if the indications are correct that the decrease in quality from just after harvest till 90 days can be upto 15 units of IVDMD (Subba Rao *et al.*, 1993). The higher importance of the storage losses in Haryana/Punjab relative to the other FS's might explain the attention which is already given to the storage of straw in these areas.

OBJECTIVE OF PRODUCTION

Different production objectives for various categories of farmers might also attribute to the wide variation in practices between farming systems. Milk production was the only objective in our model-study, but is only of secondary importance in sytems like Karnataka and West-Bengal (Table 1). More in general, animal traction is the primary objective in most farming systems in India, although milk production gains importance due to factors like reduced landholding size and tractorization (Vaidyanathan, 1981; Dhas, 1990), often accompanied by cross-breeding programs. The different animal requirements due to different production objectives will affect the relative importance of straw quantity and quality.

The effect of increased quality (TDN) in the case of low and high producing animals is shown in Figure 1a and 1b respectively where the same assumptions as listed in Box 1 are made regarding animal requirements and DMI. In addition it is assumed that:

- the amount of biomass is kept constant for both situations, i.e. 2000 kg/ha,
- CP-content of the biomass is constant at 4%.

Not surprisingly, both the number of animals at maintenance and the milk production per hectare increases with an increasing TDN-value of the available biomass (the drawn lines). More interesting is the broken line (in both Figures), which expresses the amount of extra biomass with equal TDN needed to obtain a similar increase of milk production or animals per hectare as per the increase of one unit of TDN. This extra amount is expressed as percentage of the, assumed, original amount of straw per hectare, thereby making it independent of the original amount of biomass. This percentage serves as an indication whether higher increases in animal production (either number of animals or milk production) can be realized from either increasing the quantity or increasing the quality of the biomass. For example in Figure 1b, the increase of TDN from 50 to 51% (a relative increase of 2%) has the same effect as the increase in biomass of 10%.

Quantity is the most important factor in the case of low yielding animals (Figure 1a). If the quality of straw is sufficient for maintenance (TDN $\approx$ 42), the amount of straw necessary to achieve

Figure 1 Number of animals (1a) and milkproduction per hectare (1b) related to a stepwise increased TDN-value of the available biomass (-●-), and the additional quantity with equal TDN required for a same increase (-+-).

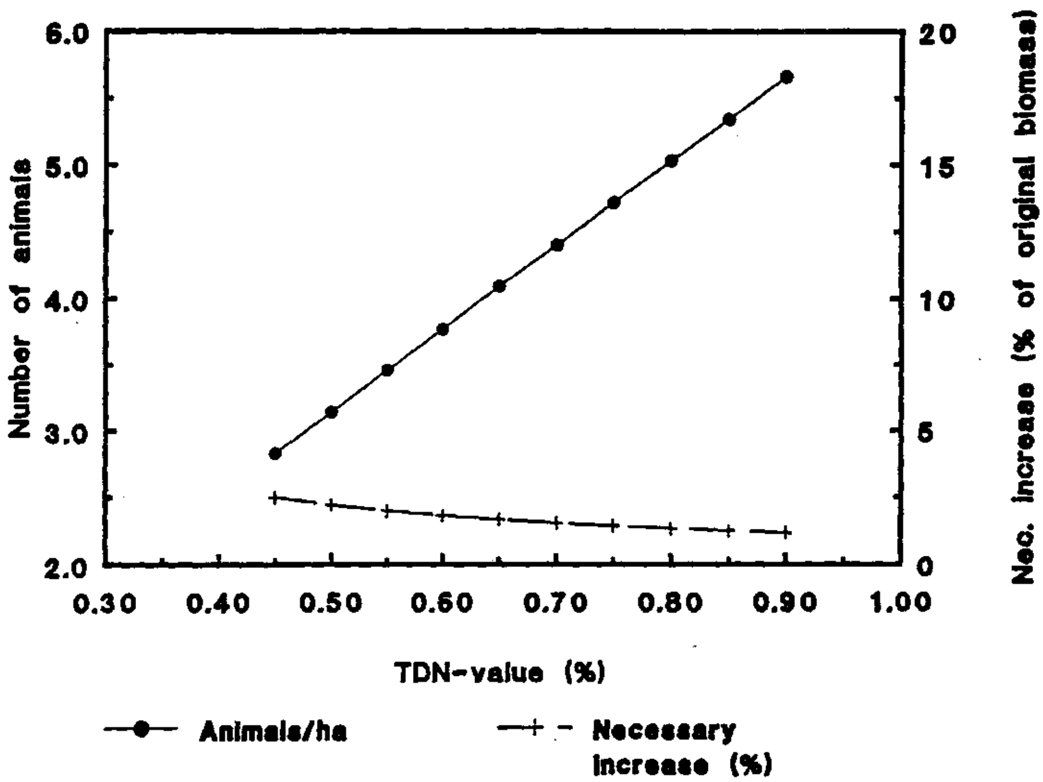
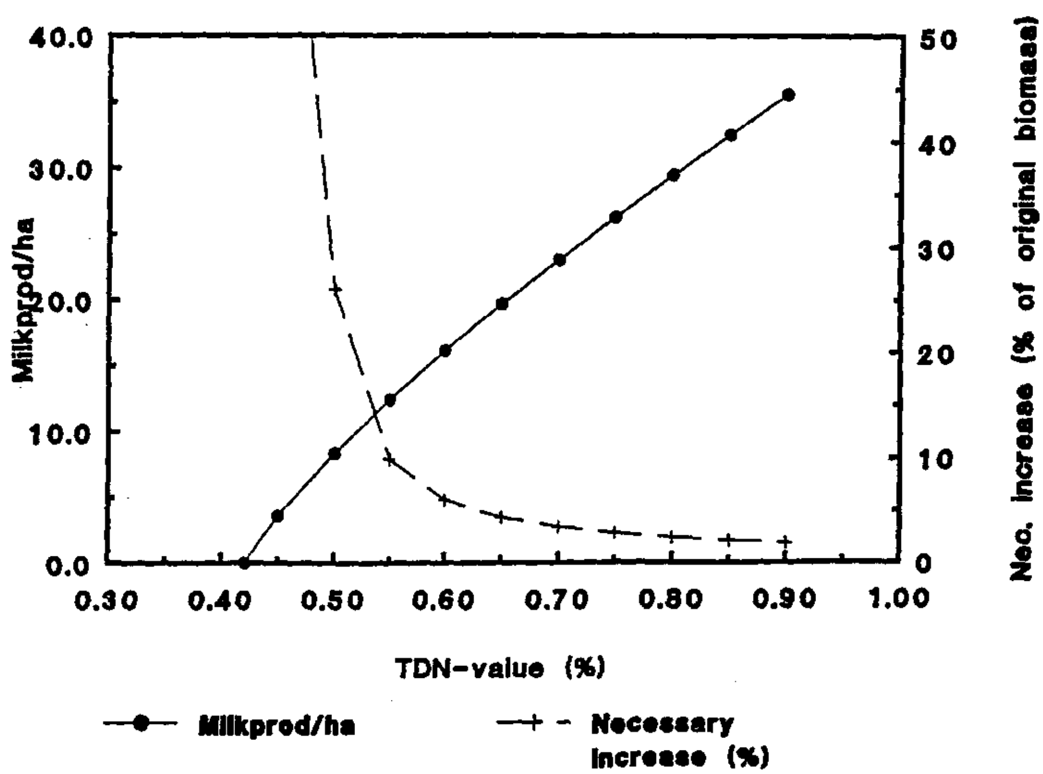


Figure 1b



a similar increase as could be obtained per unit TDN, is relatively small: around 2% of extra biomass is needed to obtain the same number of animals per hectare as is possible by an increase of one unit of TDN.
In case high milk production per hectare is the objective, this picture changes considerably (Figure 1b). In that case quality is the most overruling factor. At a TDN-level of 50%, one would need around 10% more straw to achieve a same increase as could be obtained per unit TDN.

Concluding it can be said that the objective of production influences the relative importance of straw quality and quantity and thereby the adoption rate of new cultivars. This is supported by the work of Janssen *et al.* (1990), who suggest that modern cultivars of sorghum and millet have been less adopted in important milk producing areas because of their low nutritive quality of their straws. It would be interesting to see if a similar trend can be distinguished with other types of straws. Gowda (1988) and Nygaard (1983) also relate instances where higher grain yield of a new variety does not compensate the loss in straw quality and quantity, but their observations do not specify the production objectives of the farmers, nor the availability of other feeds.

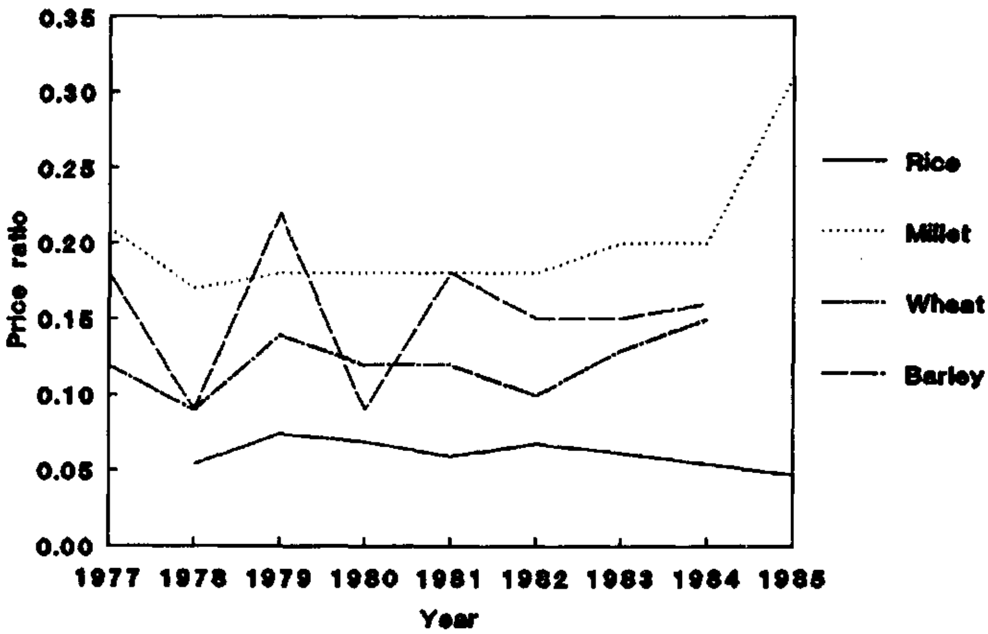
RELATIVE PRICES OF STRAW AND GRAIN

The scarcity of straw and thereby the importance of straw is (partly) reflected in the economic value of the straw. Although in general straw is becoming more valuable, the magnitude of change differs between regions and types of straws. The price ratios of straw to grain in Haryana declines from coarse straws via slender straws to rice straws (Figure 2). Depending on prevailing feeding practices per region, price ratios will be different. In Haryana for example wheat straw is preferred over rice straw but in Gujarat, rice straw is more preferred than wheat straw. This can be due to the Degnala disease occurring on rice straw in Northern India and Pakistan (Rangnekar *et al.*, 1993) or differences in the varieties grown. It indicates the need for studies of price ratios in other areas and to understand the importance of straw quality and quantity relative to grain. Price ratios at the farmgate level may be quite different from market prices, because transport cost is relatively high for (bulky) straws. It would be worthwhile to verify through field studies whether the adoption of varieties with less (valuable) straw, is lower in areas and/or for grain species having a h
straw/grain price ratio, compared with opposite situation

HARVEST INDEX

The harvest index, however, influences t
of straw. Table 3 gives an indication
straw relative to the total value

Figure 2 Change in straw/grain price ratio (Haryana state 1977-1985)



relative prices of straw and grain, and the harvest index). The preliminary conclusion is that the scope for breeding and management of straw for quantity and/or quality is less for slender species and rice than for coarse straws, due to:

- the higher harvest index for slender and rice grains,
- the lower quality of slender and rice straws (Prasad *et al.*, 1993) reflected in a low straw price compared with the price of their grains.

Therefore, for slender straws the primary objective of the variability work should be an increase in straw quality. Especially for rice straw, however, simple physiological parameters which might be used as indicators for straw quality still do not have sufficient predictive value (Soebarinoto *et al.*, 1993).

Table 3 Estimates of relative economic importance of straws

	Straw/grain ratio	Straw/grain price ratio	Straw as percentage of the total value
Coarse straw	4.0	0.36	69%
Slender straw	1.5	0.15	21%
Rice straw	1.5	0.06	9%

Note: - Slender straws include barley, oats and wheat; coarse straws include sorghum, millet, maize, etc.; rice can be considered as a seperate category (see Prasad et al., 1993).

POTENTIAL GAINS

The final choice of breeding or management for straw quantity or quality does not only depend on their relative importance for enhancing animal production, but also on the relative ease of improving the characteristics. When it is easier to increase the straw quantity than the straw quality (which seems to be true), it might become attractive to focus on straw quantity rather than on straw quality, even when quality is the most important factor influencing animal production. Quality constraints can then be overcome by supplementation. Increased quantity can also indirectly increase straw quality via increased possibilities for selection by the animals. Information on whether higher and faster gains in straw quantity can be obtained compared with gains in straw quality is deficient but some preliminary information is given for fingermillet straw by Seetharam *et al.*(1993) and for rice/wheat by Mahendra Singh *et al.* (1993).

IDEOTYPING PER FARMING SYSTEM

Specification of ideotype of cultivars (Jansen *et al.*, 1989) for different farming systems is possible on the factors discussed above in relation to the characteristics of the farming systems as described in Table 1. The value of straw as proportion of the total value can be used as indicator for the importance of the variability work, while the availability of straw relative to the availability of other feeds, production objectives and animal densities influences to a large extent the relative importance of quantity versus quality of the straw (see Table 4).

Table 4 Importance of variability work and relative importance of straw quantity and quality for three simplified farming systems

	Karnataka	West-Bengal	Haryana/Punjab
Importance of:			
-straw breeding and management	+++	++	+/-
-straw quantity	+++	++	+
-straw quality	-	++	+

CONCLUSIONS

The relative importance of straw quantity or quality depends on factors such as the availability of straw and other feeds and the objective of animal production, which are partly reflected in the relative prices of straw and grain. Breeding and management for straw quantity is especially relevant for:

- coarse straws because of their reasonable quality and, partly relate to that, their higher straw/grain price ratio;

- more remote areas with a less developed milk market and therefore a lower production per animal which allows the inclusion of straws as major proportion of the ration;
- farming systems where good quality supplements are available, or feed quantity as such is the most limiting factor (e.g. areas with relatively high animal densities).

Improvement of straw quality (here mainly expressed as TDN) is especially important for:
- rice straws, and to a lesser extent slender straws, because of their low price ratio;
- in situations where good quality supplements are scarce and where milk production is the primary objective.

The ideotype of different cultivars therefore needs to be specified per farming system. On the basis of these hypotheses, it would be possible to develop clear objectives for future work. But it is essential to verify these hypotheses by studies of characteristics of cultivars grown in different farming systems by different categories of farmers. Finally it is suggested that storage losses, deserve more attention because of their potential effect on animal production and the results which might be obtained easily and with less expense than through breeding programs.

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FARMER PERCEPTIONS OF QUALITY AND VALUE OF FEEDS - FODDER AND FEEDING SYSTEMS

D.V. RANGNEKAR[1]

SUMMARY

Mixed farming systems comprising crops and livestock have traditionally been developed by farmers in a way to be complimentary. Farmers are fully aware of the importance of livestock feeding and its direct effect on production and economics. This paper describes how farmers have assesed value of various feed resources and how they choose feed materials according to their effect on animal health and production. Examples of the benefits claimed by using some tree leaves, pods, flowers, oil seed and cakes and preference for certain varieties of cereals for straw quality are described. This paper also discusses that while scientists have developed various ways to evaluate the nutritive value of feeds, these methods and recommendation standards have very little meaning to the average farmer. Farmers have their own way to assess feed value which is mostly based on visual observations regarding palatability, effect on milk production, milk quality and animal health. The descriptions and terms used for defining feeds vary from region to region. Generally speaking, farmers have very good knowledge about local feed resources, their wuality, benefits and have developed processing methods and feeding systems based on their experience. Many times their knowledge is not appreciated and this paper describes this aspect by giving an example of the use of cotton seed and cotton seed cake. Nevertheless, there is need to verify the claims and those claims should not be accepted on face value. The paper describes how BAIF has developed a system of verification and how farmers' knowledge has helped to identify useful feed resources and to develop recommendations that are useful for farmers. Full appreciation and understanding of farmers' perceptions about the quality of feed, their ways of describing feeds and their characteristics is necessary to develop proper extension messages.

INTRODUCTION

Livestock production has emerged as a major occupation and source of income in rural areas. The direct and indirect contribution of livestock put together is estimated to be equal to or to exceed the contribution of all other agricultural commodities put together (Swaminathan, 1988; Vaidyanathan, 1989). Milk production stands second to rice considering the value of output and dairy cattle is a major component of livestock development programs in most South Asian countries. In India, dairy cattle development is considered as a major rural development activity and dairy cattle are important as a moveable asset, as an adjunct to

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agriculture; insurance against crop failure; and as a source of income, employment and draft power (Mishra and Sharma, 1990; McDowell, 1985; Swaminathan, 1988).

Feed availability, in quantitative and qualitative terms, is recognised as a major constraint to high productivity. Studies in Asian countries like Pakistan, China etc. indicate that the cost of feed accounts for 40 to 81% of the cost of milk production (Simpson, 1988). These data have been reviewed for Indian conditions by Singh *et al.* (1993). Similar ranges with respect to expenses on feeding is noticed in reports from India. Singh (1988) has reported that in buffaloes feed accounts for 41% of the cost of milk production. Yashwanth (1990), while studying livestock economy in Kerala, reports that feed accounts for 70% of the production cost and is a major constraint for livestock production. A recent report from Karnal by Rao *et al.* (1993) also shows that 71% of expenses on milk production are on feed and fodder. The studies indicate that expenditure on feed is a variable but major share in the cost of milk production. Amongst various feed items, the concentrate component accounts for the major part of expenses (Rao *et al.*, 1993), while Singh *et al.* (1988) find green fodder to be the major item of expenditure. These differences are caused by different feed supplies and levels of production between farming systems. Thus variation from region to region and according to methodology adopted is observed in the reports on the economics of milk production.

CHARACTERISATION OF FEEDS BY SCIENTISTS

Scientists attempt to evaluate and characterise feed resources, to elaborate nutrient requirements of various types of animals, and to develop feeding standards and recommendations for farmers (Ranjhan, 1993; Ranjhan and Kiran Singh, 1993). Various feed resources are characterised and described on the basis of laboratory studies. Proximate analysis has long been the main basis to characterise the feed. Digestible crude protein content (DCP) and total digestible nutrient contents (TDN) were major characteristics to describe feed materials. Thus, publications made for extension workers or farmers provide data from the proximate analysis, DCP, TDN content and in some cases mineral content for various feed resources.

Van Soest (1967) developed a fibre fraction analysis for roughages, to partly overcome limitations of the Weende system of approximate analysis. Ørskov (1989) recommends degradability studies to characterise roughages and to estimate intake. Gas production studies for characterisation of degradability of roughages has also been suggested.
Others base intake predictions on traditional feed quality parameters or animal production levels (ARC, 1980; NRC, 1987; Forbes, 1986; Ketelaars and Tolkamp, 1992).

The usefulness of DCP is increasingly questioned and alternative systems are proposed whether UDP/RDP or others (Sampath *et al.*, 1993; Walli *et al.*, 1993). Preston and Leng (1987) discuss some aspects of feed evaluation and characterisation and suggest the introduction of new systems, including estimation of bypass protein and long chain fatty acids.

Estimation of Metabolisable (ME) or Net Energy (NE) values is recommended in place of TDN for better assessment of the energy value of feeds for various functions. However, ME or NE values, with respect to ruminants, are not yet available for many Indian feed materials and TDN values are most commonly used. More recently Nolan and Leng (1989) recommend to replace ME values with intermediates in anabolic processes viz. glucogenic or nonglucogenic VFAs.

FEEDING STANDARDS

In India, the NRC feeding standards and those developed by the ICAR are most commonly used (Ranjhan, 1993 ; Ranjhan and Singh, 1993). The feeding recommendations are mostly described in terms of DCP and TDN requirements. The DCP and TDN values are available for a large number of feed resources in the country, though especially DCP is being replaced by other protein evaluations (Sampath *et al.*, 1993).

The use of feeding standards has been questioned by Jackson (1981), and Preston and Leng (1987) for developing countries. Issues such as economic considerations, large variability and poor quality of feed materials as well as subsistence production systems have been raised by these workers. The need for study of production systems in the developing countries, the feed resources and productivity of the animals for evolving appropriate feeding recommendations has been recommmended by workers like Preston and Leng (1987), Devendra (1988), Ørskov (1989) and Beever (1989). Many of them suggest approaches of strategic supplementation with NPN, lowly degradable protein, green forage, tree leaves, protected starch, long chain fatty acid sources etc. to improve utilisation as per the prevailing farming systems.

THE FARMER'S WAY OF CHARACTERISING FEED

In the early extension and training programs of the cattle development projects of the BAIF, the characterisation of feeds and recommendations for feeding were done with DCP and TDN values, major and micro mineral contents and feeding was recommended according to prescribed standards. But these descriptions did not register properly with farmers as DCP and TDN contents meant very little to them. Even if some did understand the meaning, those farmers continue to describe and choose feeds according to their own way.

A study of the traditional systems, to understand the farmers perception with respect to quality of feed and the logic behind selection of some feed material was obviously needed. Language familiar to the farmers and recommending feeding practices in line with traditional systems, would be better understood and more acceptable to the farmers. Some result of studies on traditional feeding practices are reported separately by Pradhan *et al.* (1993). Similar approaches of trying to understand traditional systems and building upon indigenous knowledge have been tried successfully in other countries (McCorkle *et al.*, 1989; Nolan *et al.*, 1989). These workers strongly recommended the need to study farmers practices and perceptions.

Such understanding could be translated into extension - training material - which may be more easily understood by the farmer. Experience of working with farmers brought the realisation of wisdom and the indigenous knowledge possessed by them in animal feeding under poor resource conditions. Matrix ranking excercises are carried out with farmers with regard to characterisation of feed material, at ten cattle development centres in three districts of Gujarat and two districts of Rajasthan. Initial results from a few centres are presented in Table 1.

A major difference between the farmer perception and that of many researchers, in characterisation or evaluation of the feed can be clearly seen. The farmer is guided by the effects that are visible on animals, while most researchers judge by the laboratory findings which do not always bear relevance for field conditons. Thus palatability, intake, refusals, effect on milk, body condition, diarrhea, constipation etc. are taken into consideration by the farmer. The roughages are primarily characterised as good, average or bad on basis of palatability and intake. The second aspect is effect of the feed on body condition, in the case of working animals, and on milk, in the case of lactating animals. We find farmers preferring straws of certain varieties of sorghum or rice on this basis as also mentioned by Kelley *et al.* (1991). In case of concentrates the major farmers' criteria are the effect on milk yield and milk fat content for milk animals and body condition in case of bullocks. Feed materials which support high milk fat production are usually ranked high. Other aspects like body condition are given second or third priority.

An attempt has been made at three cattle development centres to prepare extension literature which describe feeds in the manner the farmers would describe them and add a few points regarding energy and protein content. That literature discusses locally available feed materials and use of local terminology and use of "slang" is made for ease of understanding. Feeding recommendations are developed considering productivity of animals, feed resources and traditional feeding systems. Use of locally available and familiar material is recommmended. The results of this pilot attempt are under compilation and reported elsewhere (Rangnekar *et al.*, 1993; Rangnekar, 1993).

Table 1 Initial results of ranking excercise with farmers on characterisation and selection of animal feeds (140 farmers)

Ranking	Roughages
1	palatability
2	intake/less wastage
3	availability and cost
4	effect on body condition of bullocks and milk yield in cows
Ranking	**Concentrates**
1	palatibility
	effect on milk yield and fat % in milk (given equal ranking)
2	cost and availability
3	effect on body condition
4	animal showing regular heat signs

Note: characters most commonly considered in order of importance

DELAY IN APPRECIATION OF FARMERS WISDOM

The feeding of cotton seed, cotton seed cake and oil to milk producing animals has been a traditional practice in most parts of Western India and elsewhere. But several studies and demonstrations under research schemes that aimed to develop so-called economic rations actually tried to dissuade the farmers to use these local materials. It is only since the last decade or so that some researchers have discovered "the existence and utility of these (by-pass or slowly degradable) protein sources". The discovery is described as protein technology and almost every feed compounding unit in India is now making "by-pass protein feed". We need to appreciate that in spite of pressures from so called experts and technical officers in our country to abandon its use, the farmers continued to use cotton seed and cotton seed cake. Their belief in beneficial effect of this material is so strong that they are added by the farmers to the "balanced concentrates" and "high protein concentrates", probably also because of farmers' lack of confidence in the factory made feed. Whether the beneficial effect is due to by-pass protein or not remains a matter of scientific dispute (Sampath *et al.*, 1993)

A critical look at the ranking of material by the farmers and researchers would probably show considerable similarity in final selection. However, the description of "quality" differs. Farmers would describe cotton seed or cake as the feeds promoting milk production with high fat. The researcher would describe these feed material as "by-pass protein" for "dietary manipulation", while farmers continue it as a practice necessary to maintain productivity.

Farmers in parts of Western states are found to choose some bushes, creepers and tree leaves (i.e. *Morinda tomentosa*, *Tinosperma cordifolia*, *Alangium salvifolium*, *Harwikia binata* etc.) identified as plant material which improves milk yield and fat percentage. This approach might represent the "strategic or catalytic supplementation" using tree leaves etc. recommended by workers such as Devendra (1988) and Nolan and Leng (1989).

SOME LESS UNDERSTOOD FARMERS' CATEGORISATIONS

Hot and cold feedstuffs

Many farmers describe fodder crops and concentrates as being hot or cold. This distinction is also known from the old science of Ayurvedha for human medicine, though the classification hot and cold may differ for the same foods between countries (Schiere, pers. comm., 1991). It has been reported that farmers in West-Bengal feed bamboo leaves to freshly calved animals to promote expulsion of the placenta. These bamboo leaves are called cold feed (R.B. Singh, pers.comm). In some areas, leguminous fodder like lucerne and berseem are not fed to freshly calved or high pregnant animals in summer. Feeds are classified as hot when they are reported to cause abortions, prolapse of vagina/uterus, laboured breathing and restlessness. Maize grain is also classified as hot food. More observations and discussions with farmers are being taken up for a clearer understanding of this type of classification. An attempt can subsequently be made to find a possible logical or scientific explanation, that will be useful for extension purposes.

The difference between straws

The choice between paddy and wheat straws varies between regions/areas. In some regions wheat straw is considered superior to paddy straw while in other regions wheat straw is believed to be inferior to paddy straw. These variations are observed not only between different regions of the country (like Northern and Western India) but they are also observed within a state, where availability alone does not fully explain farmer's choice. In Northern Gujarat, South-East Rajasthan, Punjab and Haryana states where both the crops are cultivated. In Punjab and Haryana wheat straw is the roughage of choice, and paddy straw is often burned. The farmers in West-Bengal also prefer rice straw over wheat straw, whereas the latter is considered tough and unpalatable. From Punjab and Haryana there are reports of negative effects of feeding paddy straw on animal health which is attributed to high selenium content or to presence of mycotoxins (Arora *et al.*, 1975) or a combined effect of high selenium and mycotoxins. It is likely that in those regions the farmers avoid paddy straw feeding for this reason, but in North Gujarat many farmers burn the wheat straw because they prefer sorghum or paddy straw for animal feeding. Low intake and difficulty in mastication of wheat straw are reasons put forth by those farmers. These observations are being verified and chemical analysis and *in vitro* digestibility studies are in progress to understand regional differences in the nature of material. Doyle *et al.*(1986) have reviewed work on rice straw as feed for ruminants but indicate lack of systematic data on differences in palatability and intake between cultivars. Our farmers do report differences in palatability between straws.

The problem of multipurpose production

Planners and scientists often overlook that farmers keep animals not only for milk but also for a range of other purposes, such as dung, draught, savings etc. These farmer preferences are not static but can change due to changes in resource availability, demand for produce or exposure to new ideas. The choice of farmers and preference ranking is affected by factors like economy, marketing condition, government or organisational policies, feed availability etc. Farmers' preference to improve milk production is only useful when the liquid milk market is well organised. A majority of farmers in such areas even use compounded concentrate mixture when available at a low price through the Dairy Federation or other channels. In areas where marketing of cow milk is difficult and payment is according to fat content, the preference is for cheap feed resources which increase the fat content in milk. Local materials like tree leaves, pods, bushes, creepers and supplements like cotton seed cake are preferred for that.

CONCLUSIONS

The extension and training efforts and applied research are basically aimed at assisting farmers to overcome constraints in farm management for improved productivity. However, the recommendations should be related to the real farmers' problems, priorities and perceptions. They should be packaged in an acceptable and useful manner. With respect to characterisation of feed resources and their utility, it is desirable to understand the farmers psychology, the objective of keeping the animal and the traditional systems which are deeply ingrained in their mind. Describing the value of different feed material in a language which would easily register on the minds of farmers and highlighting the characteristics on the basis of issues important to the farmer, would be an effective way of making them understand the recommendation. Some farmers practices can be explained, others still need to be understood better.

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SESSION SIX

EXTENSION AND GENDER ISSUES

EXTENSION AND GENDER ISSUES

In current concepts of extension, farmers no longer are described as a client or object of the extension, to which the message from the research laboratories has to be projected. Farmers are seen as actors in the combination of research, policy makers, extension and field application. Farmers have much information to share among themselves and with research and extension services. Extension is considered as a form of communication, for exchange of information between all actors on the agricultural scene. No answers are known to many of the field problems and extension should fulfil an essential role in passing information (solutions and problems) between the actors, i.e. the researcher, the farmers, the policy makers etc. The extension service does not have enough resources to attend to every individual farmer's problem, particularly where livestock and rainfed farming takes place in highly variable situations. These conditions differ drastically from those of the rather uniform and straightforward farming systems for which simple messages were available in the time of green revolution. The latter situations had extension messages that could be applied over large areas. Particularly under highly variable farming conditions, it is impossible that research and extension gives generalized answers to each field problem.

Much extension work suffers from an obsession with transfer of technology. Such technology driven extension tends to put the emphasis on a technology that can be accepted often by only a few (progressive) farmers. Non adopters become an hindrance to the extension service rather than a challenge. A proper analysis of field problems is often lacking, and therefore the answers do not fit the problems. Obviously, much extension is therefore bound to be ineffective or even counterproductive. The emphasis on technology also takes away attention for aspects of management. A farmer may increase the income as much by better milking or heat detection as by introduction of "a new feed" or "a better cow".

For proper communication is it essential that all actors speak a common language, that they use the same concepts and that they consider each other as equals. Researchers may have to come a long way to understand farmers perceptions and goals. One example of different concepts between the actors is where a common researchers' criterion for evaluation of a feeding technique is the use of feed conversion, i.e. kg feed per kg gain. Many Asian farmers are however rarely interested in liveweight gain, and increased milk production only makes sense when the milk can be sold. What counts for a farmer (man or woman) is not the biological quantity of feed used per unit of produce but the cost (money, labour etc.) and the benefits received for it.

Traditional extension and research often incorrectly discarded common farmers practice as "unscientific". The farmers however have generally sound reasons for their way of management, and existing practices may change but often not in the direction that *is envisaged by the monodisciplinary scientist. Farmers manage both crops and livestock and have to strike a balance to obtain maximum benefit from both (see the paper by Patil* et al. *in session four). Farmer's needs will also differ between regions, socio-economic status and over time as shown in the paper of Gahlot* et al.

Quite commonly the extension message is not clear enough. The paper of Rao et al. *describes how before promoting a technology, the extension should clearly specify:*
- *the conditions under which the technology is applicable;*
- *the local modifications that may be required to apply a technology;*
- *the specific reasons for adoption, such as "should treated straw be fed" to save feed cost, to save labour, to increase butterfat or to increase milk yield.*

The perceptions of problems differs between extension agents, researchers and between farmers or gender groups (Rangnekar in session five; Gahlot et al.*; and Sangeeta Rangnekar* et al. *in this session). It is increasingly acknowledged that extension cannot be effective if it does not incorporate the farmers's point of view. Farmers are not ignorant, and generally have sound reasons not to accept certain innovations. When farming conditions are such that they lead to the adoption of innovations, a proper mix can be developed of indigenous farming knowledge and modern scientific concepts.*

Women in most rural societies play an important role in livestock production and especially small livestock is important to supply the family with food, dung, and security (Sangeeta Rangnekar et al.*; Dhaka* et al.*, both in this session). By overlooking the essential role of women, a project can fail to achieve major results or a project can have a negative impact on women/children etc. Problems arise for example when the men attend courses on feeding and milking, while the women actually perform these activities on the farm. An innovation that requires more work of the women, but that gives extra income to the men, is likely not to be accepted. This kind of problems is called gender issues, it refers to: the socially and culturally created difference between women and men; whereas the criterium for sex refers to the biological differences between men and women.*

This definition implies that :
- *gender is a social construct and it can change over time;*
- *it refers to a relation between men and women, and not to women alone;*
- *it refers to an imbalanced relation;*
- *no intervention is gender neutral.*

Gender issues therefore refer to the division of work, benefits etc. between both men and women. It is hard to generalize about the role of women and research in this area and more work is urgently required.

RECOMMENDATIONS ON EXTENSION AND GENDER ISSUES

Well planned "On Farm Trials" should be conducted to:
- identify the category of farmers for which a technology is most useful,
- assess the appropriate season for straw treatment or other technologies,
- modify straw treatment methods or other technologies where necessary, in order to develop suitable messages.

Training programs have to be organised to explain the relevance and to impart skills in application of treatment of straw to extension workers and farmers. Extension programs must take into consideration felt needs of the target group.

Extension workers need to be trained in transfer of technology and communication of the right message to the right kind of farmer. The training and extension program should consider the place of women and men and appreciate the variation between the regions and socio-economic groups regarding their role in decision making and sharing of livestock production activities.

The government and extension agencies should provide the necessary (financial) assistance to farmers initially in their adaptation of the technology.

It is important to appreciate the perceptions and priorities of farmers before recommending a new technology. Familiar words/language must be used in developing extension literature and in organising training programs for female and male farmers. The traditional feeds and feeding systems must be systematically evaluated before suggesting modifications.

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WOMEN IN DAIRY PRODUCTION: AN INITIAL REPORT OF A STUDY

S. Rangnekar[1], P. Vasiani[1] and D.V. Rangnekar[1]

SUMMARY

The paper reports initial results of studies on the role of women in backward villages of Baroda and Udaipur districts, covering about 250 families of tribal, low caste, high caste and from different economic strata. The need for tactful, innovative approaches for gathering factual information is stressed and the use of notebooks, survey forms etc. is not recommended. Indoor jobs like milking, feeding, cleaning etc. are done by women in 90% of the families. Women from rich and high caste families use hired labour. Management of male animals and fodder production are considered men's jobs. For most of the aspects, except disposal of milk, the final decisions are taken by men although women are consulted. Women from tribal and pastoralist families have a greater say in decision making than those from other social groups. Women consider livestock management as their traditional responsibility and do not realise how much hard work they put up. Women are not aware how to increase productivity of the animals. In many cooperative societies, the membership is in the name of men only, i.e. women cannot be paid, although the milk delivery is by women. Women have a good knowledge about animals' behaviour and local feed material, i.e. they can supply a good source of information as base for recommendations. Differences between regions, social and economic strata were observed with all the aspects studied. The paper recommends that in order to be effective, extension and training strategies are developed only after such studies are done.

INTRODUCTION

Livestock has a special place as a symbol of social status or wealth in production systems and cultures of countries like India (FAO, 1982). Swaminathan (1988) has rightly stated that "In India and many other developing countries, mixed farming involving crop livestock integration has been a way of life, since the beginning of agriculture. And it is widely realized that this is the only method of providing additional remuneration and employment to the small farmers and landless labour families". The importance of livestock from the view point of social aspects, multiplicity of objectives of livestock keeping, as part of mixed farming family operation has been highlighted by several workers (Wimaldharma, 1985, Mudgal, 1988, Chantalakhana, 1988, McCorkle *et al.*, 1989). Even now the number and type of livestock are indicators of the family's social and economic status in rural areas.

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Much of the work of livestock management is carried out by women while development, extension and training programs are generally not designed for involvement of women and for extending the benefits to them (Singh and Viitanen 1987; Contado, 1990). Goldy (1987) has described the status regarding gender issues and extension and since the last decade the gender issue has attracted attention of many researchers, NGO's and Government Agencies. Suddenly the need for taking up studies on women in agricultural production. The need for special programs for women is increasingly recognized (FAO, 1984; FAO, 1990; Kulandaiswamy, 1986). In many of the studies reported, observations are recorded mainly on type and amount of work put up by women (Lily 1987; Gincy *et al.*, 1988). However, the studies have to go beyond this point. They can include analysis of gender activities, resources, benefits and accessability inclusion in agricultural services (Feldstein and Poats, 1990). It is also necessary to understand perceptions of women with regard to livestock production and their involvement in decision making, particularly of women from underdeveloped areas and poor families. Women from such families have little access to agricultural livestock services.

Women in comparison with men, have less training in and access to skills and dairy technologies, as well as input and service support. For example, less than 17% of members of dairy cooperatives in India are women (Sen and Jhansi Rani, 1990). The women are difficult to involve, since for the extension workers they are difficult to communicate with and they are not confident of themselves. Even in surveys for various studies, including FSR, coverage and involvement of backward areas, families and more so of women is rather limited. Hence there is need to develop strategies which would enable involvement of such women and extending benefits of extension and training.

Some cases tend to over-stretch the gender issue by recommending that the training programs in livestock production should be made only for women. Understanding variation in behaviour/sharing of work, decision making, their perceptions, as seen in different communities, regions and economic groups would be useful. Those who work in rural areas are well aware of considerable variation in farming systems and working pattern within a region and between social and economic categories. Careful studies are needed to analyse the position of the various categories of women, to adjust the training and extension programs to the needs of relevant target categories.

While reporting FAO case studies on agriculture extension Contado (1990) has expressed concern over lack of desired efforts for extension approaches for women farmer. Contado (1990) also points out that women's access to participation in agriculture extension is one of the major issues for policy making and planning.

An attempt in the direction of gender issues was initiated by Efdé (1989), a Dutch student who studied the type of work carried out by women of different groups and ladies involvement in decision making. She faced some difficulty of language and insufficient time. However, the possibility and usefulness of such study was brought out by her attempt. Recent studies on dairy cooperatives managed by women have also highlighted problems faced with respect to funding, loaning and need for change in extension and training approaches (Mitra, 1987; Sen and Jhansi Rani, 1990). Similar concerns were expressed during the course on extension management for farm women organised at NIRD, Hyderabad in June, 1990. The national perspective plan for women raises some hope for a better future (GOI, 1988).

OBJECTIVE OF THIS STUDY

This paper presents initial results of a comprehensive study on women in dairy production in less developed area of Gujarat and Rajasthan. The study attempts to develop an understanding of the existing systems of worksharing, decision making, access to income and awareness and knowledge of the women involved in dairy production. Families from different communities and different regions, like districts of Baroda and Ahmedabad in Gujarat and Udaipur in Rajasthan were studied to understand socio-economic and regional differences. The studies aim to develop appropriate extension and training strategies for the benefit of the women.

METHODOLOGY

Families owning dairy animals were chosen for a study in some underdeveloped villages of Baroda, Ahmedabad and Udaipur districts. Help was taken of men and women associated with various activities in these villages, to facilitate introduction and dialogue. Persons associated with BAIF's and goverments activities arranged introductory meetings. Information gathering was done by a team of women involving local and outsider women and an approach of starting discussions on other subjects of women's interest was adopted. Discussions on subjects like traditional food preparations, customs, health problem of children etc. created immediate interest and opened up dialogue. Use of formal questionnaires was avoided after seeing initial reactions, where women were reluctant to talk or provide information as soon as they found that notes are being taken. For gathering information, introductory group discussions were arranged, followed by discussions with individual families and women. It was necessary to repeat visits to gather full and factual information and to note their perceptions and suggestions.

The study covers different social categories, tribal communities, pastoralists and weaker and rich farmers. The analysis was focused on subjects, which were chosen by keeping in mind the relationship with development, extension and training, and could be broadly classified into six groups (Table 1).

Table 1 Family selection and aspects studied

Economic strata	Social strata	Aspects studied
1) Landless 2) Small farmers 3) Big farmers	1) Tribals 2) Pastoralists 3) High caste 4) Low caste	1) Work sharing for animal management 2) Sales/purchase of feed, milk, animal 3) Decision making 4) Perceptions regarding livestock production 5) Knowledge and awareness 6) Suggestions/views

Observations discussed in this paper cover 145 families from three groups of Baroda district villages, 100 families from two groups of Udaipur district villages and 46 families from two groups of villages in Ahmedabad district. One group of villages in Baroda and both groups of villages from Udaipur are predominantly tribal. Rain fed agriculture is practiced and cattle development work is recently initiated in all these villages. These villages have a low literacy rate and no industry (see Table 2).

Table 2 Details of area studied

District	No. of village groups	No. of families	Irrigated rainfed	Major crops	Major communities	Major industry
Ahmedabad	2	56	Rainfed	Paddy Wheat	Pastoralist High caste Backward caste	None
Baroda	3	145	Rainfed	Maize Sorghum	Tribals Pastoralist	None
Udaipur	2	100	Rainfed	Maize Wheat Barley	Tribal High caste Backward	None

RESULTS

Work sharing in management of animals

Initial results of the study indicate that sharing of various management operations varies between regions, communities and economic categories (Tables 3, 4 and 5). By and large women from rich farmer families do not undertake any work directly. They hire labour for most jobs (Table 3). In the middle income group, particularly of the high castes, indoor jobs (feeding, milking) are done by women and outdoor jobs (sale of milk, taking animal for artificial insemination or treatment) by men (Tables 4 and 5). Among pastoralist families studied (Rabari-Bharwad) it was interesting to note that management of animals owned by the family is totally by women and men are engaged in looking after animals of other families of the village on payment. Grazing is the only operation in which men participated.

Table 3 Participation of women in dairy production: initial observations on sharing of work and decision making in the Baroda, Ahmedabad and Udaipur districts

	Poor	Medium	Rich
MANAGEMENT			
Cleaning	W100	W100	O100
Feeding	W 80	W 80	O 90
Watering	W100	W 90	O100
Milking	W 80	W 90	O100
Grazing	W 80	W 90	O100
Mang. bullocks	N.A.	M 90	O100
BREEDING/HEALTH			
Disp-Call Vet.	M 75	M 60	O 80
Adm. medicine	W 80	W100	O100
Breeding	W 90	W 90	O100
Assisting calving	M 90	M 80	O100
FODDER			
Cultivation	N.A.	M 90	O100
Harvest/Bring	W 80	W 60	O100
SALE/PURCHASE			
Sale-milk/Prod.	W 60	W 90	O100
Sale of animal	M 90	M 90	O 80
Purchase of animal	M 90	M 90	O 80
Collecting money	M 90	M 60	O 80
DECISION MAKING			
Disposal of milk	W 80	W100	W 50
Sale of animal	W 40	W 65	M 90
Purchase of animal	W 80	W 80	M 80
Breeding	N.A.	W 80	M 80
Vaccination	N.A.	W 80	M 90
Type of feed	N.A.	W 80	M 90
Type of fodder	N.A.	M 80	M 90

Notes:
W = Women; M = Men; O = Others; NA = Not applicable

Amongst the tribal families that were studied, women carried out all the management operations except in one tribal village in Udaipur where men mostly undertake operations like milking (Table 4), bringing fodder, breeding and share feeding, watering, calving and administration of medicine. Cultivation and harvesting of fodder, like other crops, is a man's job. However, fodder cultivation is not common in these underdeveloped villages. These results are quite comparable to those reported from Kerala by Gincy *et al.* (1988) who have also observed considerable variation in sharing of work. Efdé (1988) studied sharing of work between poor and others and between village close to city and away from city. She contends that in the village nearer to city most men go out for work and hence women have to take major burden of livestock. Studies from Bangladesh indicates that most indoor jobs of cattle management are by women (Lily, 1987). She also points out that, in the absence of capital, women keep livestock through a share system which generates a (relatively low) income. Livestock are however an important source of income to rural poor women, besides providing nutrient supplement if consumed by household members.

Table 4 Women in dairy production: initial observations on sharing of work and decision making (community and region-wise)

	Tribals			Pastoralist		
	B	A	U	B	A	U
MANAGEMENT						
Cleaning	W100	N.A.	W100	W100	W100	N.A.
Feeding	W100	N.A.				
Watering	W100	N.A.	W100	W 50	W100	N.A.
Milking	W100	N.A.	W100	W 50	W100	N.A.
Grazing	W 50	N.A.	W100	W 70	W100	N.A.
Mang. bullocks	Very few			N.A.	N.A.	N.A.
BREEDING/BEALTH						
Dis/call vet.	W 50	N.A.	M 90	M 70	W100	N.A.
Adm. medicine	W100	N.A.	W 80	W 80	W100	N.A.
A.I. or N.S	W 50	N.A.	M 90	W 50	W100	N.A.
Assist calving	M 90	N.A.	M 90	M 70	W 80	N.A.
FODDER						
Cultivation	No cultivation					
Harvest/bring	W 90	N.A.	M 90	W 80	W 80	N.A.
SALE/PURCHASE						
Sale - milk/prod.	W100	N.A.	M100	W100	W100	N.A.
Sale of animal	M100	N.A.	M100	W 50	W 80	N.A.
Purchase of animal	M100	N.A.	M100	W 50	W 80	N.A.
Collect money	M 90	N.A.	M100	W 80	W100	N.A.
DECISION MAKING						
Disposal of milk	W100	N.A.	W100	W100	W100	N.A.
Sale of animal	W100	N.A.	M 80	W 50	W 60	N.A.
Purchase of animal	M/W	N.A.	M 70	M/W	W 60	N.A.
Breeding	M/W	N.A.	M100	M/W	M/W	N.A.
Vaccination	N.A.		N.A.			
Type of feed	M 80	N.A.	M100	M 80	M 80	N.A.
Type of fodder	N.A.		N.A.			
Use of income	W 70	N.A.	M100	W/M	M 80	N.A.

Notes:
B - Baroda district; A - Ahmedabad dist.; U - Udaipur dist.
W = Women; M = Men; N.A. = Not applicable

Milk sales and purchases

In the rich and medium income families, particularly of the high caste, milk sales and purchases are done either by hired labour or by men of the family. Sale of milk in poorer section was not observed in some families, since there was hardly any surplus. Milk sale in others was carried out by women. In tribal families the picture was peculiar. In Baroda district villages milk was sold by women, while in villages from Udaipur (Zadol) sale of milk was done by men. In pastoralist communities milk sale was done by women. However, in most cases money for sale of milk, animal or compost is collected by men in all communities.
Exception to this phenomena are low caste families and pastoralists. An important observation is that (in most cases) dairy cooperative societies pay money to men only since they are the registered members. Sales or purchase of animal in middle or poor income group is decided by men and women jointly. The animal is brought or taken to the market mostly by men (see Table 3).

Table 5 Women in dairy production. Initial observations on sharing of work and decision making, community and region-wise

	BACKWARD			HIGH CASTE		
	B	A	U	B	A	U
MANAGEMENT						
Cleaning	W100	W100	-	0100	-	0100
Feeding	W 50	W100	-	0 90	-	0 90
Watering	W100	W100	-	0100	-	0100
Milking	W 80	W100	-	0100	-	0100
Grazing	W100	M100	-	0100	-	0100
Manaf. bullocks	Very few(M)			0100	-	0100
BREEDING & HEALTH						
Disp/call vet	M100	M 90	-	0 80	-	M100
Adm. medicine	W 90	W100	-	0100	-	0100
A.I. or N.S.	M100	M 90	-	0100	-	0100
Assist calving	M 90	M100	-	0100	-	0100
FODDER						
Cultivation	N.A.			0100	-	0100
Harvest/bring	W 70	W 50	-	0100	-	0100
SALE/PURCHASE						
Sale of milk/prod.	W 90	W 90	-	0100	-	0100
Sale of animal	N.A.		-	0 80	-	M/O
Purchase of animal	M100	M100	-	M100	-	M100
Collect money	M 90	M100	-	O/M	-	O/M
DECISION MAKING						
Disposal of milk	W100	W 80	-	W100	-	W100
Sale of animal	W100	W 90	-	M100	-	M100
Purchase of animal	W 50	W 90	-	M100	-	M100
Breeding	W 50	M100	-	M100	-	M100
Vaccination	M100	M100	-	M100	-	M100
Type of feed	N.A.	-	-	M100	-	M100
Type of fodder	M 80	M 80	-	M100	-	M100
Use of income	M 60	M100	-	M100	-	M100

Notes:
B - Baroda district; A - Ahmedabad dist.; U - Udaipur dist.
W = Women; M = Men; N.A. = not applicable

Decision making

Decision making processes are rather difficult to study. If one asks who decides on what, one gets the socially preferred answers. Hence direct questioning was avoided and "discussions in kitchen" was found essential. It became obvious that a tactful and patient approach is needed to get factual information. Discussions in the kitchen revealed that in many cases women are consulted but they do not have the final say in matters like sale/purchase of animals and use of money earned. Differences occur between communities and between rich and poor. In pastoralist communities the decisions related to animals and milk are mostly taken by women and is combined between men and women in case of use of income.

Only women were interviewed initially due to limitations of time and persons as this was an initial study. Different perceptions of men and women regarding decision making are likely (Wahyuni *et al.*, 1987). In tribal families from the Baroda district, the sale or purchase of animals, purchase of fodder, breeding aspects and use of money earned is decided by men. Women decide on the use or disposal of milk. Whereas in tribal families involved from Udaipur district most decisions are jointly taken, but the use of earned money is decided by men. In poor families of other communities most decisions are combined. It was interesting that in Ghachi community in Baroda district, income from animals was in the hands of women only.

The report of Efdé (1988) shows more or less the same trend although she has considered only feeding, milking, management and fodder crops. Earlier studies from Andhra Pradesh by Jhansi Rani (1981) and from Kerala by B. Sima (1986) covered agriculture operations in general. They report that women are more involved there with respect to decision making related to livestock, compared to men.

Perceptions of women regarding livestock keeping

The perception of women regarding livestock keeping was an interesting field of study. Rich families did not have a lot of interesting information regarding perceptions, except some communities like Rajput or Darbar who considered livestock a status symbol. In many cases women were not aware that the work they are doing could be an important economic activity. They consider the care of cows/buffaloes as part of the usual household chore which is traditionally their responsibility. Just like cleaning of the house and cooking and the care for animals is not even counted as work. However, in villages where marketing of milk is organised and the development extension programs were initiated, the women did feel that they can earn substantial amounts by selling milk. These women would like to keep 3 to 4 milch animals, a number which they can manage in terms of labour input. These women still do not perceive dairy as a commercial operation, but as a source of supplementary income and as asset which can be encashed in times of need. Cow dung is an important produce - as fuel and source of manure. For women from pastoralist community, male progeny from the cows is more important than milk because they can be sold as draught animals. Grazing of animals is considered essential to maintain the health of the animals. Milk rich in fat is considered better quality product than low fat milk. Tribal women found it difficult to imagine that milk production could be an important economic activity and that a cow is capable of giving large quantities of milk. After a few visits most women showed keen desire to know about high producing cows, artificial insemination (A.I.), quality fodder etc. Particularly from traditional cattle breeder communities, many women strongly believe that animals should be washed and kept clean to keep them healthy.

Knowledge and awareness regarding animal husbandry

Compilation and analysis of information of this aspect is still incomplete, but a few salient points are described here:

A majority of the women, except a few from remote tribal areas, are aware of the need for better quality feed to obtain higher production. The women may not be in a position to describe feed quality in terms of protein, energy etc., but many of the women know that Mahuva flowers, oil cakes, grains etc. are good quality feed (Pradhan *et al.*, 1993). Some of the women even identify certain weeds, tree leaves, creepers as good quality fodder for livestock. Women are well aware of peculiarities, habits, behaviour of individual animals and such animals are fed and handled accordingly. The women who supply milk to cooperative societies have some awareness about the need for clean milk, and the value of fat and "solids non fat" content of milk. However, most have little awareness of artificial insemination or cross-breeding since in some of the villages such work was not initiated. Such women were not believing that cows and buffaloes can be made pregnant by artificial insemination. Many of the women were aware that vaccinations are carried out, but very few realised the need and the usefulness. Many use indigenous methods for treatment of ulcers after cases of foot and mouth disease, for tick control, diarrhea etc. In case of difficult calving they usually take the help of a local "specialist" who is generally from a traditional cattle breeders community (Bharwad/Gujjar). Almost none of the ladies knew about the importance of colostrum feeding soon after birth. In fact, many respondents believe that colostrum should not be fed for some time. The majority knows that green fodder is of better quality than straw or dry-grass and the difference between good and bad quality fodder is judged on the basis of animal's acceptance. However, cultivation of green fodder was never seriously considered because land holdings and irrigation are constraints. Knowledge and awareness about cattle keeping in women from rich families was very low. Many of those ladies are not aware of the milk yield of their cows and the animals and sheds of many of them were in dirty condition while animals and sheds from the neighbouring poor families were much cleaner.

Suggestions and additional observations

It is worth mentioning that women from a village near Baroda were tired of surveyors and students. Other workers keep coming 2-3 times a year and ask all sorts of questions. The women were unable to understand motives and objectives of these surveys and wondered why these outsiders concerned themselves with their way of life with all sorts of suggestions. The senior author had to convince some women, at the initial stage, that she had come to learn their food preparations.

The majority of the women desires to learn about high producing dairy animals. As the discussions proceeded, many ladies gave suggestions and asked questions about what they would like to learn more about: fodder crops, ensiling, urea treatment, grass storage. Further analysis of which women would prefer which information is yet to be done. The ladies were aware of the effect of good quality fodder on milk production. While their awareness and uncanny observations on animal behaviour can be an asset, the illiteracy is a limiting factor. We should design training programs accordingly. An attempt at functional literacy would be very useful as many women expressed desire to learn reading and writing. Women can not be away from the home for a long period and are therefore averse to resident courses. Ladies prefer discussions (talking) over lectures and training programs or extension meetings need to be organised accordingly.

Such studies on women as well as training and extension programs are best carried out by women with proper exposure and orientation.

CONCLUSIONS

This report is of a preliminary nature, but some tentative indications and observations are summarised hereunder.

Methodology of surveying:

- such studies need repeated visits, informal and innovative approaches to establish contact, so as to get factual information and generate discussions to gather perceptions, views and suggestions. Use of note-books, survey forms, need to be avoided and tendency of haste for gathering information should be curbed. Women do not communicate freely in presence of men. Young women are not free in presence of old ladies or elderly persons and domination of women from higher, social and economic strata is also evident. Thus for detailed study, the groups should be as homogeneous as possible. Women knowing the local language should be preferred for efficient gathering information.

Sharing of work and decision making:

- the study indicates differences in work sharing between economic and social strata and between regions. Some of the vital jobs in dairy production like feeding, milking and medicine administration are done by women. These aspects should be considered for extension training. Men cannot be ignored since they take critical decisions. It would be wortwhile paying more attention to women from pastoralist and tribal communities considering their role in dairy production.

Awareness and knowledge:

- most women are not aware about the hard work that they put up during the day since livestock management is carried out as a traditional responsibility which they do not consider as work. Women have a good knowledge about animals' behaviour and effects of good quality feed, fodder etc., but they have little information about aspects such as diseases or reproduction. In most cases women deliver the milk but the money is collected by men. Membership, registration is in the name of men, in most of the dairy cooperative societies and hence the payment is made to men.

Constraints of extension and training services:
- major changes are needed in the approach of extension and training services if women are to be involved and benefitted, or even if development programs are to succeed at all. There is need to develop women's team for extension and training to facilitate communication. It is necessary to recognize the high illiteracy amongst women and difficult communication, particularly, with respect to women from poor, backward communities. The usual approach of lectures, distribution of notes and pamphlets needs to be changed and suitable audio-visual material be developed. The training programs need to be practical oriented since women would like to do things by themselves and learn while doing. They cannot stay away from home for longer periods and cannot remain attentive to long lectures. The passing of information from men to women is poor and majority of men are not very keen to educate women. It would be worth to promote registration of women as members of milk society or developing women's dairy Cooperative Society. This task should be handled tactfully and slowly.

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ROLE OF FARM WOMEN IN DAIRY FARMING SUB-SYSTEMS IN RURAL INDIA

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SUMMARY

This study aimed at ascertaining the socio-economic status of farm women and analysing the labour utilisation in dairy farm operations. The study was conducted in Karnal and Nadia districts of Haryana and West Bengal. The results indicated that the expenditure on food and non-food items of an adult female was lower than an average member of the family in both the districts. The proportion of female workers was about 49 percent of total workers in the sample households of Karnal district as against 47 percent in Nadia district. The average female labour participation in various operations of dairy enterprises was 33 and 32 percent in Karnal and Nadia districts respectively. The female participation was found to be highest in the preparation of milk products. Next in the order of importance were collection and chaffing of fodder/grasses, cleaning of cattle-sheds and animals and feeding of animals in the sample households. It was observed that farm women played a dominant, as well as supportive role, in decision making pertaining to various activities of dairy farming. On average, about 52 and 30 percent of female respondents knew about various improved technology for dairy farming in Karnal and Nadia districts respectively, but their adoption by the sample households was 35 percent and 10 percent only. Thus, it may be concluded that special attention is required in animal husbandry and dairy production to improve the existing skills of rural women because they have shown to be actively involved in the dairy farming sub-system, both on aspects of production and of processing.

INTRODUCTION

Human resources are one of the most important production factors in any process of economic development. Women constitute about 47 percent of this vital resource in India (Census, 1981). There are 331 million females in the country, of which the rural females constituted about 77 percent, their major occupation being agriculture and agro-based enterprises. The literacy rate amongst rural females was observed to be only 18 percent as against 48 percent of women in urban areas. Rural females also suffer more from nutritional inadequacies as areas compared to males. It is known that the majority of farms in India are family farms where the major portion of farm work is done by the farmer and his/her family members. It is generally the wife of the farmer who shares the brunt of the burden in addition to her major assignment as the housewife. Thus, rural women share

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abundant responsibilities and perform a wide spectrum of duties in running the house and family (Saini, 1983) as well as attending to farm activities including animal husbandry and extending a helping hand in rural artisanship and handicrafts (Reddy, 1975; Verma, 1978; Singh and Singh, 1981; Singh and Usha, 1983; Pandey *et al.*, 1986). Although a large majority of rural women spend a lot of time on farm, home and other supporting activities, the official governmental statistics show that women constitute only 21 percent of the work force in India. The low profile of female labour participation in the country conceals a great deal of work done by rural women and this invisibility is a great handicap in the planning of a development strategy for rural women. Although the tasks performed by the males are becoming mechanised, the women continue to toil in labour intensive or unskilled jobs (Kaur *et al.*, 1986). Women also have less limited job opportunities in modern occupations/trades as they have access to the required training in various trades and new technologies.

During the last decade, much attention has been paid to promotion of the welfare of rural women to bring them into the mainstream of socio-economic development by encouraging their work participation in desired spheres. Animal husbandry enterprise with appropriate production technologies has a potential for socio-economic transformation of rural women. A number of studies were conducted to ascertain the activities performed by women. The tasks, which were exclusively performed by women, were preparation of milk products, milking of animals, care of calves and pregnant animals (Kanjla, 1980), bringing fodder from the field, feeding animals, giving water to animals, cleaning of cattle shed and making dung cakes (Puri, 1975; Chakravarty, 1975; Dhar, 1978; Usha and Singh, 1982; Sangwan *et al.*, 1986). However, the participation of women, in farm work varies between farming systems and regions/states of the country. Keeping in view the importance of women's participation in dairy enterprise in the context of employment and income generation in rural areas, the present study was under taken with the following objectives:

i) to study the socio-economic status of farm women in different categories of households;
ii) to examine the female labour force and their utilization in various dairy farm operations;
iii) to assess the role of farm women in dairy farm decision making alongwith their knowledge and adoption of a number of modern dairy farming technologies.

METHODOLOGY

This present study was conducted in the Karnal district (Haryana state) and Nadia district (West Bengal). A multi-stage random sampling technique was adopted to select the female respondents. Amongst 10 administrative blocks of the Karnal district and 17 blocks of Nadia district, two blocks from each district were randomly selected. From each of the selected blocks, one village was randomly choosen. A list of the milk producer households was prepared for each selected village according to the land owning status i.e. landless labourers, marginal farmers (upto 1 ha), small farmers (1.0 to 2.0 ha), medium farmers (2.0 to 4 ha) and large farmers (above 4.0 ha). A sample of 100 households from each district was randomly selected on the basis of probability proportion to the number of households in different farm size categories. Thus, in all, 200 respondents constituted the sample for the study. An adult women from each household was interviewed by female investigators with the help of the well structured schedule. The data were collected from the respondents at one point of time for the agricultural year 1989-1990 and subjected to tabular analysis.

RESULTS AND DISCUSSION

Socio-economic profile

Family size is an important factors influencing labour availability for crop and livestock work on the farm. The average family size was about 6 persons in the sample households of both Karnal and Nadia districts (Table 1). Comparing the male and female members, it was noted that there were about 863 and 905 females for every 1000 males in the study area of Karnal and Nadia district respectively. This indicated that sex ratio in these districts is in favour of men. The same picture is reflected in the All India Census, 1981 Figures, where for every 1000 males, there were 933 females. Unlike the rest of the world, sex ratio in India has been decreasing throughout the country. However, interestingly the sex ratio favoured females on small farms of Karnal and medium farms of Nadia district. A positive association was observed between family size and operational holdings of the sample households of Karnal and Nadia districts. The average size of land holding was 2.90 and 1.39 hectares in Karnal and Nadia district respectively. The overall average number of milch animals kept by different categories of households was 3 in Karnal district against only about one milch animal in Nadia district. The keeping of small milch herds by landless, marginal and small farmers could be explained in terms of inaccessibility, both socially and economically, to bulk fodder and crop residues, lack of funds for purchase of milch animals and, inadequate space to house the animals.

This is especially true of dairy farming which requires a better level of management than conventional crop farming. The analysis of data pertaining to level of education revealed that on an average, about 53 percent and 64 percent of the family members were literate in Karnal and Nadia district, respectively. The literacy rate in females was 38.79 percent in Karnal district as compared to 57.14 percent in Nadia district. The maximum number of illiterate females were in the categories of landless labour and marginal farmers in both districts. Ahuja (1974), National Committee on Women's Education (1975), Sangwan (1979), Rahi

(1991) have reported in their respective studies, conducted in rural areas of different states, that poverty, social customs and traditions, social discrimination between boys and girls, early marriage and lack of good women leaders to promote women's education facilities, were the reasons for the low level of women education. Other reasons for low education were preference for household and field work, existence of co-education and absence of vocational training and employment after higher education.

Table 1 Socio-economic characteristics of the sample households

Particulars	Category of Households					Total/ Overall
	Landless	Marginal	Small	Medium	Large	
KARNAL						
No. of Households	46	20	9	13	12	100
Family size (Nos.)	5.65	6.05	6.55	7.38	8.42	6.37
Sex Ratio (per '000'males)	883	779	1034	809	871	863
Literacy Status (%)						
Family	37.93	55.21	75.47	67.91	82.02	52.94
Female	22.58	35.56	77.78	60.00	73.17	38.79
Size of holding (ha)	-	0.66	1.64	3.27	7.15	2.90
Milch animals (Nos.)	1.72	2.55	3.78	4.92	6.00	3.00
NADIA						
No. of Households	35	32	20	8	5	100
Family size (Nos.)	5.42	5.84	5.75	6.75	6.60	5.79
Sex Ratio (per '000'males)	939	889	797	1077	941	905
Literacy Status (%)						
Family	58.42	59.36	67.83	81.48	75.76	63.73
Female	55.43	53.49	54.91	75.00	62.50	57.14
Size of holding (ha)	-	0.44	1.44	2.81	5.01	1.39
Milch animals (Nos.)	1.17	1.09	1.05	1.38	2.80	1.23

To study the economic status of farm women, data on expenditure incurred per month on food and non-food items was worked out for an adult female as well as on a per capita basis for all the members of family in Karnal and Nadia districts and these are presented in Table 2. It was observed that the overall expenditure incurred by an adult female per month was about INR 215 and INR 194 as against per capita expenditure of INR 239 and INR 203 on the sample households of Karnal and Nadia district respectively. The per capita and per adult female expenditure on food items accounted for about 61 and 52 percent in Karnal district respectively as compared to 75 and 74 percent in Nadia district. Further, milk and milk products were the major component of expenditure on food items followed by cereals in Karnal district whereas cereals recorded the highest expenditure in Nadia district. However, the expenditure on milk and milk products was very high (88.99) on per capita in Karnal compared to the expenditure on adult female. Among non-food items, expenditure per adult female on clothing was the highest in both the districts. Thus, the results indicated that the expenditure of an adult female was lower than of an average member in the family in both the districts.

Table 2 Expenditure on food and nonfood items on adult female (INR per month)

Items	Karnal		Nadia	
female	Per capita	Per adult female	Per capita	Per adult
FOOD ITEMS				
Cereals	32.24 (13.50)	36.26 (16.87)	69.52 (34.17)	69.82 (36.02)
Pulses	7.78 (3.26)	14.18 (6.60)	13.68 (6.72)	15.09 (7.78)
Vegetables	9.61 (4.03)	11.48 (5.34)	17.00 (8.36)	15.45 (7.97)
Fish, mutton and eggs	-	-	23.96 (11.77)	19.40 (10.01)
Fruits	7.40 (3.10)	6.35 (2.96)	11.91 (5.85)	13.62 (7.03)
Milk and milk products	88.99 (37.27)	44.33 (20.63)	17.51 (8.61)	11.07 (5.71)
Sub - total	146.02 (61.16)	112.58 (52.40)	153.58 (75.48)	144.45 (74.52)
NON FOOD ITEMS	92.72 (38.84)	102.26 (47.60)	49.88 (24.52)	49.39 (25.48)
Total	238.45 (100.00)	214.84 (100.00)	203.46 (100.00)	193.84 (100.00)

Notes:
- Figures in parentheses indicate percentage to total
- data from one study only

Women labour and its utilization

The availability of female labour reflects the earning potential of the households. Depending on the local, economic, social and cultural forces, the female participation varies in different parts of the country. Therefore, it is essential to study the existing female labour force in different categories of households in a particular area or farming system, for their better involvement in various development programs.

Table 3 shows that the average number of female workers per household was higher on most of the categories of households in Nadia district as compared to Karnal district except on small and large farms. However, the overall proportion of female workers to total workers was about 49 percent on the sample households of Karnal district as against 47 percent in Nadia district. Interestingly, among all categories, marginal farmers recorded the lowest proportion of female workers to total workers in both the districts.

Due to rapid industrialisation, young men from villages are shifting to neighbouring towns or cities as job-seekers. Therefore, data on human labour use were analysed to assess the extent of female labour participation in dairy enterprise (see Table 4).

Table 3 Female labour force on the sample households

Category of Households	Karnal		Nadia	
	Av. No. of female workers	Total workers	Av. No. of female workers	Total workers
Landless	1.32 (51.16)	2.58	1.77 (48.10)	3.68
Marginal	1.30 (44.07)	2.95	1.78 (45.30)	3.93
Small	1.89 (48.59)	3.89	1.75 (46.10)	3.80
Medium	2.15 (45.84)	4.69	2.25 (53.00)	4.25
Large	2.67 (50.86)	5.25	2.60 (50.00)	5.20
Overall	1.64 (48.66)	3.37	1.85 (47.40)	3.91

Note:- Figures in parentheses indicate percentage of female workers to total workers

Table 4 Female labour utilization in dairy farming

Category of households	Man days / Household / annum			
	Karnal		Nadia	
	Female labour	Total labour	Female labour	Total labour
Landless	70.38 (46.42)	151.62	59.73 (39.83)	149.95
Marginal	56.58 (25.96)	217.91	59.19 (38.40)	154.13
Small	80.30 (28.99)	276.99	60.45 (32.03)	188.73
Medium	119.04 (31.57)	377.07	82.92 (34.04)	243.58
Large	118.92 (25.91)	458.98	111.25 (26.05)	427.01
Overall	80.66 (33.28)	242.35	74.71 (32.11)	232.68

Note: - figures in parentheses indicate percentage to total

The results of human labour utilization in dairy enterprise indicated a positive relationship between human labour use and farm size in both the districts. On an average, 242 and 233 MED (man equivalent days) were utilized per household during the year in Karnal and Nadia districts respectively. This study used the disputable ratio of 1 MED of 8 hours; 0.75 MED is a female day; 0.50 MED is a children's day. However, Usha and Singh (1982) while studying the human labour utilization in dairy observed that about 153 man equivalent days were utilized per household in dairy enterprise during the year. The proportion of female labour use (including both family and hired) in dairy enterprise in Karnal district was highest (46 percent) on landless labour households and lowest (26 percent) on the large farms, the average utilization being 33 percent. In the case of sample households of Nadia district, the female labour use varied between 26 percent on large farms to about 40 percent on landless households, the average utilization being about 32 percent.

With a view to assessing the contribution of women to dairy enterprise, the data on human labour use in various operations of dairy enterprises during the year were analysed for different categories of households. The preparation of milk products recorded the highest share of women followed by cleaning of cattle-sheds and animals, collecting and cutting of fodders/grasses and feeding of animals on the sample households of Karnal district (see Table 5). This accounted for about 100, 80, 32 and 25 percent of the total labour use in each operation, respectively. However, in the case of Nadia district, the contribution of females was also highest in the preparation of milk products followed by feeding of animals, chaffing of fodders/grasses and cleaning of cattle-shed and animals which accounted for about 86, 60, 57 and 44 percent of the total human labour use in each operation. It was noted that the average female labour utilization was 33 and 32 percent in Karnal and Nadia districts respectively. However, Usha and Singh (1982) observed in their study on the weaker sections, that female labour utilization was higher than that of males and children in almost all the dairy farming operations except bringing fodder/grasses from the field. The important role of women in the dairy sector is also revealed by the findings of Sangwan *et al.*(1986), Satnam Kaur and Punia (1988) and Apte (1989). Our study pertains to all land size category of farmers, whereas the study of Usha and Singh (1982) was focused on weaker sections (landless, marginal and small).

Table 5 Operation-wise human labour utilization and contribution of females in dairying

Operations	(Man-days / household / annum) Karnal		Nadia	
	Human labour use	% of share of female	Human labour use	% of share of female
Bringing/cutting of fodder	77.78	32.33	58.80	25.87
Chaffing of fodders	24.42	24.66	19.25	57.45
Feeding of animals	20.00	25.36	15.64	60.29
Grazing	10.58	2.07	46.51	10.64
Giving water	29.75	16.87	17.32	32.10
Handling of animals	18.03	21.86	12.95	36.91
Cleaning of shed and animals	21.46	80.44	28.68	43.84
Health care	8.47	18.10	14.72	34.44
Milking	12.30	19.88	10.25	34.63
Making milk products	13.43	100.00	1.04	85.58
Marketing of milk/products	6.13	21.43	7.53	21.28
Total	242.35	33.28	232.68	32.11

Women's participation in decision making

The involvement of women in the decision making in various dairy farming activities indicate the women's interest and awareness in them. About 21 percent of the decisions of dairy farming activities were taken by the women alone in the sample households of Karnal district as compared to 17 percent in Nadia district (see Table 6). Women's participation in decision making was relatively higher than that of men in the use of milk and milk products, care and management of calves and feeding of concentrates in Karnal district which accounted for about 70, 64, 30 and 27 percent respectively. However, in the case of Nadia district, the role of farm women in decision making was found to be higher for activities such as feeding concentrates to animals and care and management of calves accounting for about 42 and 38 percent respectively. The data further revealed that about 34 and 36 percent of the decisions of dairy farming activities were jointly taken by men and women in Karnal and Nadia districts respectively. However, the decisions on increasing/decreasing the herd size and artificial insemination in cattle were mainly taken by men in both the districts.

Table 6 Participation of farm women in decision making in various activities of dairy farming

Activities	Karnal				Nadia			
	Women only	Men only	Both	All members	Women only	Men only	Both	All members
Choice of animals	9.00	25.00	48.00	18.00	13.00	30.00	36.00	21.00
Cattle-shed construction	7.00	23.00	53.00	17.00	11.00	50.00	33.00	6.00
Purchase of milch stock	17.00	19.00	52.00	12.00	15.00	30.00	44.00	11.00
Increasing/decreasing animals	22.00	31.00	39.00	8.00	6.00	51.00	32.00	11.00
A.I. in animals	-	21.00	62.00	17.00	13.00	56.00	25.00	6.00
Treatment of diseases	18.00	34.00	35.00	13.00	10.00	33.00	45.00	12.00
Vaccinations	3.00	50.00	39.00	8.00	8.00	34.00	44.00	14.00
Feeding of concentrates	27.00	27.00	30.00	16.00	42.00	17.00	32.00	7.00
Care & weaning of calves	30.00	18.00	36.00	16.00	38.00	13.00	38.00	11.00
Selling of milch animals	27.00	29.00	33.00	11.00	13.00	30.00	45.00	12.00
Utilization of milk	70.00	15.00	11.00	4.00	19.00	41.00	31.00	9.00
Selling of milk	64.00	15.00	17.00	4.00	24.00	34.00	35.00	7.00
Purchase of draught animal	1.00	70.00	15.00	14.00	9.00	33.00	41.00	17.00
Borrowing of Loan	11.00	63.00	20.00	6.00	13.00	41.00	22.00	24.00
Purchase of dairy equipment	16.00	45.00	32.00	7.00	13.00	32.00	38.00	17.00
Insurance of animals	19.00	53.00	17.00	11.00	11.00	43.00	26.00	18.00
Overall	21.00	34.00	34.00	11.00	17.00	35.00	36.00	12.00

Dairy Farming Technologies

It is very difficult to identify appropriate dairy farming technologies relevant to farm women as few or none have been developed keeping in view the role of farm women in these activities. Therefore, the level of their adoption is very low. In order to study the extent of knowledge about various animal husbandry practices and their adoption, data were analysed and are presented in Table 7. This Table shows that 92 and 84 percent of the female respondents were aware of cross-breeding technology in Nadia and Karnal districts respectively, but only 36 percent and 69 percent of the sample households adopted this technology. On an average, about 62 and 39 percent of the female respondents had knowledge of various dairy farming practices in Karnal and Nadia districts respectively. The data further revealed that farm women were aware of various dairy husbandry practices such as vaccination against contagious diseases, cross-breeding, artificial insemination and pregnancy diagnosis, improved feeding, tick control and dehorning in Karnal district but their adoption by the sample households was 81, 69, 60, 49, 52 and 57 percent respectively. However, in the case of Nadia district, female respondents were aware of cross-breeding, tick control, vaccination against contagious diseases and artificial insemination and pregnancy diagnosis but their adoption by the sample households was only 36, 33, 20 and 11 percent respectively. Low level of adoption of improved technologies could be attributed to lack of support from the head of the family, financial constraints or just lack of initiative on the part of rural households, besides inadequate extension services.

Table 7 Knowledge and adoption of dairy farming technologies

Technologies	Karnal		Nadia	
	Known(%)	Adopted(%)	Known(%)	Adopted(%)
1. Cross-breeding	84	69	92	36
2. A.I. & P.D.	81	60	49	11
3. Vaccinations	90	81	58	20
4. Tick control	76	52	78	33
5. Improved feeding	77	49	33	6
6. Green fodder production round the year	13	10	17	4
7. Deworming	36	20	26	6
8. Dehorning	69	57	1	1
9. Castration	36	18	-	-

CONCLUSIONS

Rural women play an important role in farming activities and livestock keeping. They perform supportive as well as dominant roles in decision making pertaining to various dairy farming operations. Therefore, training programs should be organized with special reference to dairy farming activities performed by farm women. Further, efforts should be made to develop appropriate technologies which can be adopted by women at home such as simple and small appliances for processing of value added milk products with longer shelf-life. Sincere efforts are, therefore, needed to mobilise the resources represented by women.

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UREA TREATMENT OF STRAW - AN EXTENSIONIST'S POINT OF VIEW

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SUMMARY

Many efforts have been made to transfer urea treatment of straws to farmers. This paper discusses experiences in three different farming systems prevailing in Gujarat, Haryana and Karnataka and addresses some of the issues relevant for the farmers' adoption of urea treated straw (UTS). The extension programs under study were not preceded by an exante analysis to establish whether farmers would be likely to benefit from UTS technology. As a result, after initial on-farm trials, many farmers, discontinued the use of this technology. The paper discusses the adoption of UTS in the context of four elements of the adoption process, i.e. the technology itself, the farmer, the extension agency and infrastructural facilities. Data were collected through an interview from a cross-section of farmers that were exposed to UTS technology in the three states. Most of the respondents perceived UTS as a simple, somewhat profitable and low cost technology provided that urea was supplied free of cost. Many failed to appreciate the value of UTS in increasing milk production. The farmers were of the opinion that urea can be better used in crop production rather than on treatment of straws and they did not perceive the need for UTS. Negative experiences associated with UTS were risk of fungal spoilage, sticky dung or loose dung and poor keeping quality, though these experiences are not a rule. Other reasons for discontinuation of this technology included the nonavailability of urea, straw, labour and/or water. Questions to be answered before taking this technology to the field, include i) to which category of farmers is this technology useful ii) what message is to be communicated to the farmers iii) what are the long term benefits to the farmers in continuously feeding UTS and iv) what is the most appropriate time for treatment?

INTRODUCTION

The shortage of feeds and fodders in terms of quantity and quality is considered to be a major impediment for increased milk production in the country. Since there is increasingly less land for fodder production, the crop residues become more important as animal feed. Animal nutritionists try to improve the quality of straws through various chemical treatments. Research has convincingly shown that urea treatment of straw is technically

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feasible and that it improves the feeding value by increasing digestibility and intake (Jayasuriya and Perera, 1983; Amrith Kumar *et al.*, 1993; Verma, 1987; Schiere *et al.*, 1988). Feeding of urea treated straw (UTS) increases the milk yield and persistency (Verma *et al.*, 1987) compared with feeding of untreated straw. Practical problems and their solutions are discussed by Schiere and Sewalt (1988), Bhaskar *et al.* (1988), Walli *et al.* (1988), Mahendra Singh *et al.* (1993) and efforts are underway to transfer this technology to the farmers.

This paper discusses the adoption of the technology in three different farming systems in Haryana, Gujarat and Karnataka where no *ex ante* analysis was done to establish which farmers might need UTS or not. After initial trials therefore many farmers discontinued the use of this technology (Table 1). This article addresses some of the issues which are relevant for the adoption of this technology. Data were collected through an interview from 65 sample farmers who were exposed to treatment of straws. The general information of the respondents and the methods adopted by them in treatment of straws is given in Tables 2, 3 and 4.

ADOPTION

The decision to apply an innovation and to continue its use is called adoption (Van den Ban and Hawkins, 1988). The process of adoption begins from the first stage of hearing about the technology to the final decision to use it or not. Rogers (1983) explained the process of decision making with the help of four stages viz. knowledge, persuasion, implementation and confirmation. This process of adoption depends upon a number of factors such as
- technology itself;
- the farmer;
- the extension agency and
- infrastructural facilities.

The Technology

Research is being done to develop technologies for the benefit of the farmers, but not all the technologies find favour with the farmers. This leads often to technology driven extension, where the message takes precedence over the problem (Röling, 1988). Not more than one fifth of the available agricultural technology has been absorbed in the villages, benefitting only one-tenth of the farmers (Reddy, 1980). Some technologies are adopted faster than others because of differences in terms of profitability, simplicity, initial cost, observability of results, compatability with the existing norms and customs of the society in which the farmer is living (Rogers, 1983). Urea treatment of straw is one such simple technology that may however not be useful everywhere.

Table 1 Status of farmers on adoption of Urea Treatment of straws (1989)

Item	Gujarat	Haryana	Karnataka
No. of farmers that tried treatment	60	59	19
No. of farmers that reported success	48	57	19
No. of farmers using the technique	7	0	2

Table 2 General information about the respondents

Characteristics	Gujarat N = 17	Haryana N = 59	Karnataka N = 19
Farm size (range in ha)	2 to 6	0.5 to 12	0 to 18
Herd size (range)	3 to 6	2 to 27	2 to 18
Sale of milk	Often	Often	Regularly
Source of UTS message	BAIF	NDRI	NDRI
Year of start	1987	1987	1988
No. of times treated	1 to 3	1 to 3	1 to 12
Amount of straw treated at a time (kg)	400 to 1000	1250 to 2500	25 to 100
Duration of feeding (days)	21 to 90	30 to 60	30 to 60

Table 3 Methods adopted in treatment of straws

Particulars	Gujarat	Haryana	Karnataka
Straw used	Paddy	Paddy	Fingermillet, Paddy
Duration of treatment (days)	14 to 21	21	7
Covering material	Bags, mud	straw, fertilizer bags	Polthene bags

Table 4 Source of different inputs for urea treatment

Inputs	Gujarat	Haryana	Karnataka
Straw	Farmer	Farmers	Farmers
Urea	BAIF	NDRI, farmers	NDRI, Farmers
Labour	Family	Family	Family, hired
Covering material	Farmer	Farmer, NDRI	Farmer
Water can	Farmer	Farmer	NDRI

Table 5 Perceptions of farmers about UTS

Characteristics	Gujarat	Haryana	Karnataka
Profitability	somewhat	somewhat	high
Initial cost (if urea is supplied freely)	low	low	low
Observability of results	not easy	not easy	easy
Type of technology	simple	simple	simple

Farmers compare the relative advantages of feeding urea treated straw with the existing practice of feeding untreated straw with or without other feeds. In addition, the farmer compares the alternate uses of urea on crops or for straw treatment, especially when there is limited availability of cash to buy urea. The perceptions of the farmers of the three regions (Table 5) showed that except for a few farmers in Karnataka, the respondents rated UTS technology as somewhat profitable, provided urea was supplied free of cost. Urea is one, but not the only expense required for treatment. Sri Lankan work showed that the relative cost of urea is 22 - 61% of total expenses, depending on the local situation (Schiere and Ibrahim, 1989). All the respondents perceived straw treatment as a simple and easy to understand technology.

Table 6 Observations of farmers on the effect urea treatment of straws on animal production

Particulars	Gujarat	Haryana	Karnataka
Increase in milk yield	marginal	marginal	marginal
Intake of straw	increased	increased	increased
Reduction in concentrate consumption	no change	no change	little
Physical condition* animal	improved	no change	no change of
Reduced wastage of feed	substantial	no change	substantial
Dung consistency	loose	loose	loose

Note: * often noted as luster of the haircoat
** no clear observations were made on fat percentage of the milk

There was a wide variation among the responses of the farmers on the observability of the results. Haryana farmers indicated that the benefits of this technology were not easily observable, probably because:

- TS was fed alongwith berseem and oilcakes;
- no reduction in the quantity of either berseem or concentrates was applied;
- TS was fed to all categories of animals;
- TS was fed for only 2 to 3 months.

Milk production increased from 0.5 to 1.25 litres per day per animal after introducing TS (Walli *et al.*, 1988; Rangnekar, 1988; Amrith Kumar *et al.*, 1993). The respondents in our survey observed a marginal increase in milk yield and a substantial increase in the intake of TS (Table 6). In some cases, commercial farmers of Karnataka could produce the same quantity of milk at less cost by substituting some amount of concentrates with TS. Mahendra Singh *et al.* (1988) reported that a commercial large dairy farmer in the Pantnagar (Uttar Pradesh) area has continuously used the technology because it reduced the cost of milk production. Commercial farmers, by virtue of their entrepreneurial qualities and access to the market, would like to adopt technologies which reduce the cost of milk production. If TS is a cheap feed which can be used as a partial replacement for relatively expensive concentrates or cakes, without having any adverse effect, TS is a viable technology for any commercial farmer, whether small or large. A majority of the farmers in all the three regions appreciated the increased intake of TS.

These observations lead one to conclude that urea treatment of straws is marginally superior to feeding untreated straw, but the results can be measured in biological and economic terms, or in terms of feed quality, intake etc. as shown in Table 6 and as discussed below.

Farmers' perceptions

Some farmers adopt innovations faster than others owing to different perceptions and attitudes. Resource Rich Farmers (RRF) by virtue of their better resource position, greater exposure to mass media and extension agencies, and by their risk bearing capacity are likely to use of new technologies better than Resource Poor Farmers (RPF) (Chambers and Jiggins, 1986). The technology which is suitable for one farming system may or may not be suitable for other farming systems. Similarly, the needs of farmers vary according to their socio-economic status, socio-cultural setting, farming conditions etc. Three essential conditions which should be met to adopt the technologies are:

- the farmers must want to follow the technology;
- the farmers must know how to follow the technology and
- the farmers must be able to follow the recommendation (Van Dissel and Röling, 1989).

Farmers must either perceive the need for the technology or the technology must be able to create the need to initiate the process of thinking in the farmers (Rogers, 1983). Adoption depends partly on the strength of, and the need for the technology . Whether urea treatment of straws is perceived as a need by the farmers or whether the extension service is able to arouse the need among the farmers is the question yet to be answered, and strongly different between farming systems.

Initially urea treatment was evolved as a technology to improve the nutrit ve quality of straws and TS can be fed to all animals which are normally fed ith untreated straw. However, it is difficult to realise its benefit especiall in animals that yield low levels of marketable produce (milk, meat). RRF do not require this technology unless there is a change in their cropping pattern. It is possible to reduce the area under green fodder by switchin on to UTS feeding. RPF, especially landless cattle owners, who maintain th ir animals mostly on dry fodder may need this technology but they cannot affo d the extra expenditure, however little, though they save concentrate. Hence it is necessary to categorize the target group which needs this technology most.

The opinions of farmers that had experience with UTS indicated that urea can often be better used in crop production than in the treatment of straws, when urea is in short supply. Though farmers

Box 1 Characteristics of farmers in the different farming systems that undertook to try straw treatment

Haryana Farmers (irrigated rice/wheat)

- rearing of cross-breds, non-descript cows and buffaloes. Not much differential feeding between classes of animals. Working animals, pregnant animals and animals in milk are fed with concentrates. The rest of the animals are maintained with *ad libitum* green fodder and dry fodder.
- sale of milk whenever there is surplus.
- not much concerned about cost of milk production.
- grow green fodders such as berseem + mustard, oats, maize, jowar etc.
- wheat straw is the choice dry fodder.
- no interest to use paddy straw because:
  * there is a fear of Degnala disease (Arora *et al.* 1975; Bhatia and Kaira 1981; Bakshi *et al.* 1986.
  * farmers generally burn their paddy straw
  * medium and large farmers use combine harvester even at the cost of paddy straw to avoid the risk of grain spoilage due to rains.
- poor farmers feed their animals with paddy straw and little quantity of green fodder.

Karnataka farmers (urban cattle owners)

- rearing of cross-bred cows and buffaloes.
- sell milk almost regularly by commercial dairy farmers.
- feed concentrates, fingermillet or paddy straw with very little quantity of green fodder.
- labour shortage.
- small savings per animal appears to be quite substantial when the herd herd size is bigger especially in farms that were more commercially oriented including some owned by Christian missionaries. Some other farmers also perceive the advantages of feeding treated straw.

Gujarat farmers (tribal farmers, upland farming)

- few cross-breds, small farmers also keep sheep and goats.
- rearing of cows and buffaloes.
- sale of milk whenever it is surplus.
- maintain animals on pearlmillet, grasses and rice straw in addition grazing 4-6 hrs/day on village and forest land.
- paddy straw is preferred over wheat straw.
- green fodder cultivation is negligible.
- in the tribal belts the farmers feed tree leaves, flowers, creepers and weeds to milking and working animals only.
- resource poor farmers cannot afford to purchase concentrate.
- small quantity of home made concentrates (mix of damaged grams and gram husk) is fed to milking animal.
- resource rich farmers purchase balanced cattle feed.

were convinced that urea treatment increases the nutritive value of straws, many failed to appreciate the contribution of UTS to increased milk production, or saving of concentrate. The characteristics of farmers who conducted on-farm treatment trials of straws and of whom only a few continue to adopt the technology are given in Box 1. It can be seen that the farmers were quite a variable group, resulting in different rates of adoption.

Extension agency

Several studies on the impact of extension concluded that the quality of extension is a major factor in farmers' adoption of modern varieties and inputs. Extension can accelerate the diffusion of innovation (Gershon *et al.*, 1985). However, extension can only work effectively (Röling, 1988)
- if it satisfies the farmers' objectives;
- when government objectives and farmers' objectives coincide;
- government objectives are packaged in such a way,that farmers see them as beneficial for themselves.

There is sufficient evidence that frequency of extension contact and closeness with extension agents are positively related to the knowledge and adoption of (dairy) technologies (Subramanian, 1982; Mahipal, 1983; Kokate, 1984; Rao, 1987).

Simple and highly profitable technologies spread faster than complicated and less profitable technologies of which the results cannot be observed easily. Subsidies can accelerate the adoption of such technologies. Urea treatment of straws is a technology which can be adopted easily and speedily by all farmers with very little external assistance. Provision of urea and or polythene may have to be temporarily organized by the extension agency. Only the adoption may not be attractive everywhere as is also evident from the papers in session 4 of this workshop.

The role of extension is to translate the technology into messages which can be easily understood by the target group. The discussions with the farmers revealed that they received no clear cut messages regarding the usefulness of UTS in all the regions. Most emphasis was laid on its effect to increase milk production, but effects on health, labour saving or saving of supplement might be equally relevant (see Table 6). The extension needs to be aware of the farmers' perception of benefits as discussed by Rangnekar (1993). Some literature is becoming available on the increase in milk production at different levels of UTS feeding and in animals with different production capacities at the institute level, which can provide information on the maximum expected yield through this technology (see session 4 of this workshop).

The extent to which the extension agents understand an innovation is important factor for effective transfer of technologies. The extension workers in Haryana appear to be sceptical about the use of this technology especially during October and November due to scarcity of labour in October and availability of berseem in November. In addition, these workers were even confused because of contradictory messages. Earlier they were advised not to feed paddy straw to prevent the occurrence of Degnala disease in animals (Arora *et al.*, 1975; Bhatia and Kaira, 1981; Bakshi *et al.*, 1986). Now they have to communicate "Feed treated [paddy] straw". However, it is good to note that Degnala disease was not a problem in animals fed with treated paddy straw in our survey.

Infrastructural facilities

Experience in India teaches that lack of adequate infrastructural facilities is one of the reasons for slow adoption of technologies. In the absence of inputs such as urea, straw, water, covering material, labour or space for storage it is not possible for the farmers to treat the straw.

Similarly, any technology will give maximum effect only under certain conditions and research indicates that the following conditions are required for the adoption of urea treatment of straws (Schiere *et al.*, 1988, M. Singh, 1988, Kiran Singh and Schiere, 1988, Amrith Kumar *et al.*, 1993, Walli *et al.*, 1988).
- scarcity of green fodder/grasses;
- availability of clean and dry straws at a low price;
- high cost of concentrates (relative to straw);
- remunerative milk price.

In Haryana it was observed that paddy straw was available with all the respondents at a time when berseem was also available in plenty. The farmers fed berseem as well as TS to all animals. Hence, the strategy could be to encourage the farmers to reduce the area under fodder so as to enable them to substitute the green fodder with the TS and at the same time maintaining the level of milk production. Another alternative could be to increase the herd strength. The introduction of combine harvesters for the paddy fields, may result in decrease of the quantity of paddy straw. The supply of urea seems to be a limiting factor in Haryana as many farmers indicated their preference to adopt the technology only when urea is supplied to them free of cost, partly because they are spoilt with subsidies. Farmers also express the difficulty to feed only the lactating animals with TS, because of the inconvenience involved in feeding the animals separately.

In some areas there was difficulty to collect sufficient water for treatment, especially in Gujarat.

In Karnataka, the storage space for the treated straw was a problem encountered by nine respondents. Farmers also experienced the problem of straw stacks being exhausted faster because of increased intake of TS.

CONCLUSIONS

Many issues are to be addressed before starting an extension effort to promote the use of TS or any other technology. Some of these issues are discussed in recent literature (Schiere and Ibrahim, 1989; Schiere *et al.*, 1988; Sewalt and Schiere, 1989; Rai *et al.*, 1993; Singh *et al.*, 1993; Amrith Kumar *et al.*, 1993) and other recent workshop proceedings including this one (see the literature list of session four). The issues include:

- the need to determine for which category of farmers and which seasons is TS feeding most useful. The message is likely to be attractive for farming systems where straw is abundantly available and cheap compared to (concentrate) supplements, where animals yield a reasonable level of saleable produce, and where critical inputs are available.
- the message to be communicated to the farmers is to be defined clearly. Depending on the farming system it maybe one or more of the following
  * feed UTS to reduce the cost of milk production,
  * feed UTS to increase feed intake,
  * substitute expensive berseem or other feeds with cheap UTS,
  * treat straw to increase quality of straw or to save money,
  * make the straw useful through Urea Treatment,

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FELT NEEDS OF DAIRY FARMERS
A CASE STUDY FROM CATTLE DEVELOPMENT CENTRES IN SAURASHTRA, GUJARAT

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SUMMARY

Farmers needs can be categorised in felt and unfelt needs. To secure active participation of the people, a development program must address needs which are recognised or felt as important by the community. This paper describes a study that was conducted to ascertain the needs of the cattle owners in different cattle development centres - through personal observations and rapid survey with the help of field extension workers. The study revealed different needs between socio economic groups and stages of development. Rich farmers mostly expressed the need to maximize crop production while the poor farmers group wanted upgrading of local cows and subsidy for cattle feed. The very poor farmers group gave the highest priority for asset based income generating programs, i.e. programs which ensure improvement of productivity and market values of their assets like cow, sheep and goat etc., or nursery plantation at their small farms. Poor farmers were also most concerned about the maintenance of livestock during droughts as frequently faced in the last decade. A considerable number of respondents of the very poor group wished to maintain their status quo besides an improvement of small ruminants. Farmers of the rainfed areas stressed status quo satisfaction even more, i.e. they were risk averse. In initial stages of development the major felt needs concerned calf rearing, cattle feed subsidy and treatment of repeat breeders. In those conditions no need was expressed for the improvement of straw quality. Communities in a medium stage of development demanded knowhow on better feeding, health care and integration of crop and livestock production. In advanced stages of development the need was to maintain optimal economic feeding, and methods to ensure survival of livestock during drought. The need for the upgrading of straw quality and treatment was only felt in this last stage i.e. five years after the start of the development project in the study area. Concluding it can be said that extension needs to address different issues according to the target groups and stages of development. Improvement of feeding is important but not always the top priority for all groups.

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INTRODUCTION

"When you need salt, sugar won't do - Yiddish saying."

Farmers rear livestock to satisfy various needs. In India and other developing countries, livestock provides the farmers with food, draft, power, fuel, and fertiliser (Amir and Knipscheer, 1989; Cranstone, 1969). In addition, particularly for small farmers, animals are a mean of storing wealth or to provide security against risk of low crop yields particularly in rain fed areas. For large farmers, animals are a symbol of prestige and provide social status. The needs for development therefore vary from farmer to farmer depending on factors such as socio economic status, agroclimatic conditions or infrastructural facilities, as discussed elaborately in the first session of this workshop.

The term "needs" implies conditions such as necessity, requirement, urgency and indispensability. Needs can be arranged on a hierarchy of priority at any point of time. People try to satisfy the needs by behaving in a particular way which they feel will enable them to reach a goal because human behaviour is goal directed (Davis, 1981). Needs can be classified in different ways, but psychologically they can be simply categorised into felt and unfelt needs, based on whether the needs are recognised or not.

The participation of the target population is vital for the success of any development program. To secure active participation of these people, a development program must address needs, which are recognised or felt as important by these people. In other words: "If you need salt, sugar won't do".

The needs should also be made specific, rather than using general terms. For example: a general term "low productivity" must be broken up in causes like poor feeding, reproductive problems etc. (Iqbal Shah *et al.*, 1990; Collinson, 1987).

Another aspect of development is that the agency has to make farmers aware of their needs. Maalouf (1989): "Even with clear extension policy directions and adequate extension infrastructure, an extension service is unlikely to be effective, unless its programs are relevant to the current problems and needs of the farmers and the recommended technologies are appropriate for solving their problems". Hence analysis of needs of the cattle owners is of utmost significance in the successful planning and implementing of any development program. Methods to identify farmers problems, needs and appropriateness of methods are discussed in this workshop by Patel *et al.* (1993). This paper is a case study to determine changes of felt needs within different socio economic groups and stages of development. Specific aspects of differences between gender groups are highlighted in other case studies by Rangnekar *et al.* (1993) and Dhaka *et al.* (1993).

THE CASE STUDY

The BAIF Development Research Foundation has taken up development projects throughout India. One such a cattle project in the state of Gujarat aims to improve the milk production and to provide gainful self employment to the cattle owners. A study was conducted to ascertain the needs of the cattle owners in 10 sample villages of Saurashtra in Gujarat state. Information was elicited through detailed surveys and personal observations of the field extension workers and rapid surveys. The data pertaining to 343 farm families spread over 10 villages in 4 districts of Saurashtra region of Gujarat were analysed as presented in Table 1.

Table 1 Details of sample sizes

District	Type of farmers			Stage of development		
	Resource rich	Poor	Very poor	Intial	Medium	Advanced
Bhavnagar	12	47	39	0	0	98
Junagadh	29	26	42	0	97	0
Amreli	20	35	53	68	40	0
Rajkot	18	11	11	40	0	0
Total	79	119	145	108	137	98

GENERAL INFORMATION ABOUT THE AREA

The sample respondents include approximately 70% resource poor farmers (small, marginal, landless cattle owners; annual income less than INR 6400) and the rest were big farmers (non poor group, land holding was more than 2 hectares and annual income more than INR 6400). The study was carried out in a rainfed area with an annual rainfall between 300 to 500 mm in the last three years. This region has experienced severe drought in the year 1986-1987. The average land size was 4.6 acres out of which 3 acres were rainfed. The big farmers use diesel engines and wells for irrigation. The agriculture is mostly traditional. Major crops grown are millets, sorghum and wheat. Groundnut, cotton and sugarcane are some of the cash crops grown in the area. On average each family owns about 4 animals which consist mainly of buffaloes and local cows. The number of cross-bred animals owned by the sample respondents was negligible. As many as 55% of the families owned bullocks which were predominantly of local breed. Buffalo is the animal of choice for milk production and local cows for bullock and dung. The region has nomadic tribes like Rabaries and Bharwads. These tribes are traditional cattle keepers. They keep large numbers (20 - 200) local bred cows, maintained on stray grazing and sale of milk and males mainly. The Bharwads also keep sheep and goats and sell goat milk.

ANALYSIS OF NEEDS

The needs of the sample respondents were analysed at different stages of the development programs and were related to the regional and socio economic differences between farmers. The shift in the perception of the needs was also analysed for different stages of development, measured by the duration of development program activities in those areas. Two methodological problems are that:

- the person who does the survey may be associated with particular (development) program. The farmers may express their need towards what they expect from that person. Also, the interviewer may interpret answers according to his/her own professional bias.
- the time effect was measured by taking villages at different level of development (i.e. involvement of BAIF in that village), i.e. village effect is confounded with effect of years of development.

Neither of these two problems are expected to invalidate the points made in this paper.

Regional differences

The relative importance of need is influenced by the physical socio-economic environment and its resultant farming systems. Therefore, the needs felt by the farmers of the irrigated area are different from that of the rainfed area. The farmers in the irrigated area demanded more mechanisation and they wished to maximize the production. Farmers in rainfed areas are more at the mercy of nature and more risk averse, hence they aim at status quo satisfaction. The families from rainfed areas derive just sufficient income by working as agricultural labourers in irrigated fields of big farmers. Hence better labour renumeration was the primary need expressed by them.
The preference in the irrigated area was for cash crops which fetch better profits. On the contrary, in rainfed area the farmers rely upon millets for their basic food needs.

The farmers in irrigated areas own comparatively more productive animals which are maintained mostly on crop residues and on common resources or wastelands. Jodha (1986), on the basis of data from seven states in India, emphasises the role of common property resources in sustaining a number of animals for draft and livestock production, specially of the rural poor.
Irrigated areas were comparatively well developed with more infrastructural facilities including market for agricultural produce. The cropping intensity is higher and the area provides year round employment. Hence, many young and able people from rainfed areas migrate to irrigated areas for work.

The small families who own low producing animals living in villages with no marketing facility did not want any change or extra efforts with reference to animal production. Farmers with large families in the same villages like to increase production by soaking, chaffing and spraying salt water on crop residues before feeding to animals. The goat is the animal of choice for small families in rainfed area because of its small size, hardy nature, high rate of reproduction, easy disposal and useful both for milk and meat. The resource poor farmers were mostly under the pressure of imposed obligations and the norms of elite groups in the village community. The basic needs of this depressed group were food, seeds for crops, consumptive credit in the slack season, and bullock for work. These bullocks are mostly provided by the resource rich farmers. Resource poor farmers cannot afford to increase the cost of feeding of their low producing cows and goats which are maintained on crop residues and grazing lands, due to very limited financial reserves and access to credit.

Socio-economic differences

Felt needs also differ between resource rich farmers and poor farmers as already indicated earlier. They are summarized and depicted for Saurashtra in Figure 1. The explanation of the five main needs is given in Table 2. The resource rich farmer is characterised by higher land availability which is mostly irrigated. These rich farmers have a higher capacity to accept risk, more cash at hand and better ability to influence the decision of village institutions. Moreover these resource rich farmers have a high mechanisation in agriculture and ability to exploit the use of technologies coupled with inputs and technical services. Almost the reverse was true for poor farmers who depend on outside agencies for their development.

The needs of the resource rich farmers centered around maximisation of crop production. They need mechanisation to replace labour on the farm, economic fodder production methods, upgrading the nutritive values of the crop residues etc.

The poor farmers were more dependent on each other within the group and hence they were more committed to the group for their security and satisfaction of basic needs. Resource poor farmers also depend upon resource rich farmers for employment as well as for agricultural inputs. Resource poor farmers demand asset based labour intensive income generating programs, i.e. like crop and livestock production and financial help during off season to maintain their family and livestock.

The very poor farmers of low social strata expressed the need for improvement of goats rather than cow production. This lowest farmer class was least interested in risky exotic cows because it was beyond their economic capacity to maintain these superior cows. They need animals which can be maintained at almost no cost, maybe low yielding animals, and can provide employment to old or very young members of their family. Uma Shankari (1989) explains the differences in economics between small farmers. The poorest farmers believe in status quo satisfaction and felt the need for not disturbing their "peace" by forceful technological interventions.

Figure 1 Felt needs as expressed by different farmers categories

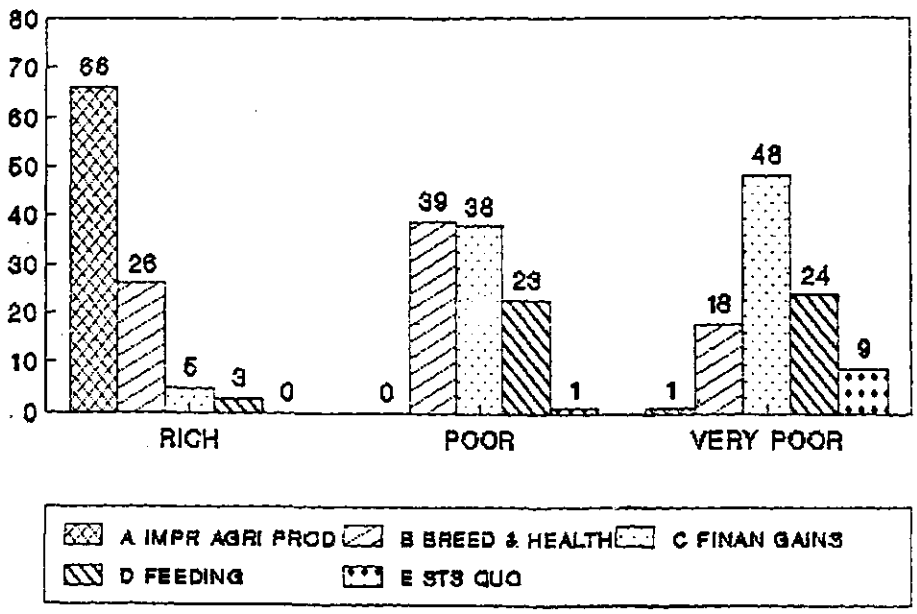
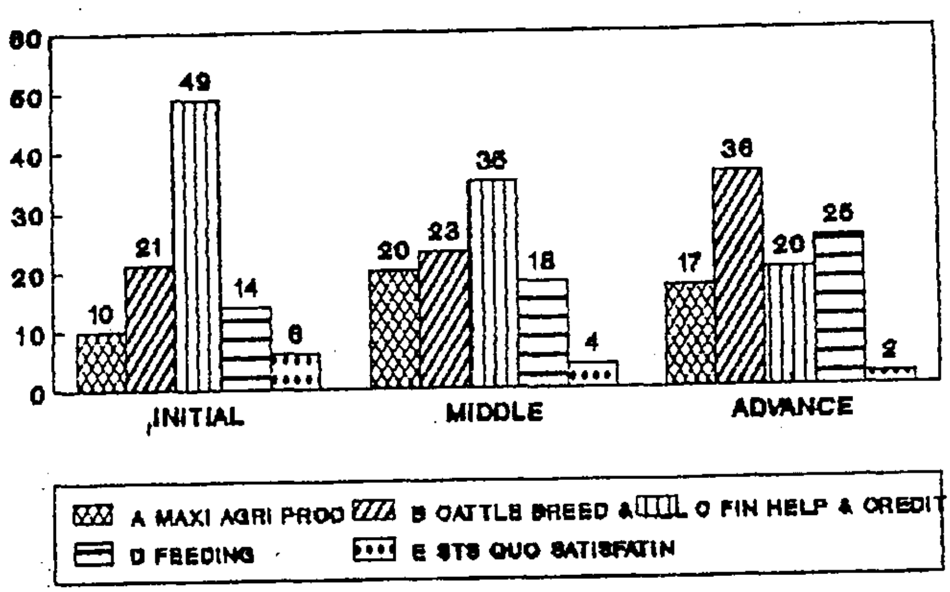


Figure 2 Shift in needs with stage of development



Some poor farmers expressed their need for a suitable cropping pattern with food crops, fodder crops and perennial fodder trees, of which the products were required for their food needs and livestock maintenance.

Stages of development

The BAIF cattle development project aims at increased milk production through cross-breeding of less productive cows with exotic bull semen in order to provide avenues for gainful self employment of the target group. The implementation of the project also involves organisation of training programs for farmers to impart knowledge and skills related to improved dairy husbandry practices to the target group. About 60 farmers are being trained every year in each of the centres (of the study area). The training needs of the beneficiaries were also assessed to chalk out suitable training programs. Some of the important training needs as generally perceived by the beneficiaries are:
- knowhow for fertility management;
- utilization of farm waste;
- preparations of nutritious/balanced cattle feed at home;
- profitable changes in feeding practice, etc.

However, the needs of the farmers change from stage to stage in the process of development, and the results of our study are summarized and depicted in Figure 2. During the implementation of the cattle breeding program, the discussions with the farmers revealed the need to introduce of important supporting programs like fodder development and non livestock activities like fruit plantation. The implementation of such additional programs at the same development unit need better trained staff. Hence there is also an important need to train and orient staff to enrich their knowledge and skills to consequently help and train the field beneficiaries in other fields than livestock development.
Many dormant (or unfelt) needs come to surface, or become priority need when earlier felt needs are satisfied. As the process of development gains momentum, there is greater participation of the target group in the program which further leads to greater interaction among farmers as well as between farmers and the field extension officers. Consequently the priority of the needs changes, depending upon the stage of the development.

Initial stage

With the introduction of artificial insemination and continuous education of the farmer in the village the felt needs expressed by the farmers were for:
- the treatment of repeat breeders;
- credit for food and contingencies for farm and family;
- training as described before under "stages of development";
- better methods of calf rearing.

There were no felt needs expressed for methods to upgrade the quality of straws.

Middle stage

There was a clear shift of the farmers preference from local cows to cross- bred cows over time, after observing the performance of the cross-bred cows. A similar result was reported by Uma Shankari (1989) in her study in Chitoor (Andra Pradesh). However, the bullock is still an important animal and the felt needs at this stage were:
- knowhow about better feeding to ensure better production;
- management of animals (shed design, dehorning etc.);
- better health care of the animals;
- care for cross-bred calf;
- integration of crop and livestock production.

Advanced stage

At this stage the beneficiaries of the development programs were able to appreciate the role of technological interventions. The farmers priorities shifted to more profit maximisation and the needs were:
- to maintain optimal production;
- fertility campaigns to improve and maintain reproductive performance of the animals;
- economic feeding of animals;
- improved varieties of fodder seeds;
- feeding methods to ensure survival of their animals specially in drought period;
- market for animals.

These findings differ from the observations of Kokate (1984) that the perceived needs of tribal dairy farmers of Maharashtra were:
- need for irrigation for fodder production;
- higher price for milk;
- regular veterinary checkup and marketing infrastructure.

The differences may be due to the differences in area and target group.

CONCLUSIONS

No extension service will be successful in popularization of sugar, when the first felt need is for salt. However, farmers can also be unaware of some needs, i.e. but dormant needs exist and extension also has a role in creation of awareness. These preliminary studies suggest that extension for development needs to address issues according to particular needs that differ among others between socio-economic groups and stage of development. Improvement of feeding is important but not always the top priority for all groups at all stages of development. Also, livestock development agencies should be alert for the need of development in non-livestock sectors.

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TRADITIONAL LIVESTOCK FEEDING SYSTEMS IN TRIBAL AREAS OF GUJARAT AND RAJASTHAN

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SUMMARY

This paper highlights the need to study traditional livestock management and feeding systems, in tribal areas or semi arid rain fed regions. Such a study is required before finalising extension and training programs and recommendations for feeding and management of livestock. The paper is based on field experience of the BAIF and emphasises the need for a changed outlook towards extension and training work in remote, underdeveloped areas, with socially and the economically poorer sections of the society. The perceptions and priorities of the target population need to be better understood. The so called "modern" methods of livestock management should be appropriate, for resources, traditional systems and related local conditions. A clear understanding of traditional practices and concepts helps to make recommendations which are easy to understand and adopt by poor farmers. Use of familiar language/words, considering the local slang, should be made in training or extension. Examples are given of traditional management and feeding systems which were subsequently found to have scientific logic. However, not all the traditional beliefs and systems are to be propagated and accepted. Some traditional systems may have lost relevance, due to changing of conditions, others may still be very useful. Much is to be learned from the farmer, and researchers, development agents and extension workers, should adopt the approach of sharing of information. Farmers are not more rigid than the scientists, but innovative. In underdeveloped areas and with weaker sections the farmers' priority is survival before high production.

INTRODUCTION

Agriculture and livestock keeping are a major occupation source of and livelihood, and an essential part of the culture of the rural society. This has resulted in the rural community adhering to certain practices with respect to crop as well as to livestock production, as if they are part of tradition. Poorer sections of the society, for example those from underdeveloped areas in the tribal belt extending from Rajasthan to Maharashtra, adhere more strictly to traditional practices than communities in agriculturally and industrially developed areas. These poorer sections are often characterised as backward and unwilling to adopt new technologies. At least, this is how many development and extension agents would describe them, who are educated and trained in the Universities located in developed cities.

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Since a few years BAIF became involved in implementing livestock development programs and subsequently evolving integrated development programs for this entire tribal belt. This was a good opportunity to understand the existing conditions in these underdeveloped areas, and to develop an approach which can be described in the modern jargon as systems/holistic/participatory approach. The BAIF workers needed to understand how best they can work as catalysts to help the farmers to improve their productivity in a sustainable way. Before advising any change it is necessary to understand the traditional methods, the reasoning behind those methods, the results observed and then decide whether there is need to intervene and change the system. By experience we have learned that a drastic change and many changes at a time are not accepted by the farmers, particularly not by those from the low income and low education group. Another important aspect of this systems approach was to become confident ourselves, i.e. to know that the recommended change will be more beneficial than the existing practice.

The BAIF extension officers are local young people with farming background from rural areas, but they never bothered to study traditional practices. Traditional practices are usually brushed aside as part of day-to-day routine. Another reason for not studying these practices is the attitude of most of the technical staff. The feeling is that "traditional is backward" and "traditional is to be changed to modern or scientific practices", with the connotation that the traditional practices are "unscientific" (Verma and Singh, 1969). Many traditional extension and training approaches are based on this concept. But there is change, and a realisation in the "scientific" community and particularly among those involved in extension and training to look at the situation differently (Chambers, 1983; Gupta, 1989; Gupta, 1990; Bunch, 1985; Waters-Bayer, 1989; Rhudes and Booth, 1982; Chambers *et al.*, 1989).

The purpose of this paper is to study and understand prevailing, practices in tribal feeding systems, in order to incorporate these experiences in the extension programs.

METHODOLOGY OF THE STUDY OF TRADITIONAL PRACTICES

Through experience we learned that there is need to study prevailing farmers' practices, to confirm and ratify the claims and make an attempt to find logical explanations for those claims and in some cases relate the beliefs and practices with the resources, the marketing conditions, agro climatic situations etc. Thus a sequence of study emerged as follows:

- in the listing and screening some of the beliefs and traditional practices, narrowing them down to those which are observed by a large number of farmers and where the claims were confirmed by a sizeable number (more than 500 farmers spread over 2 or 3 districts).

- asking the extension officers to observe the results of feeding some chosen material on production, health etc. as claimed. Aspects of management and the feeding system are recorded in detail.
- to undertake investigations in an attempt to find scientific explanations with the help of laboratory studies, pilot farms or with cooperating farmers. This step is still to be taken.

The feeding practices, which are being examined are indicated in Table 1.

Table 1 Some traditional feeding practices for dairy animal and results claimed by farmers from semi-arid and tribal areas of Gujarat and Rajasthan

Material used	Method of feeding	Type of animal commonly fed	Farmers' claims
Cotton seed and cotton seed cake	Cooked/soaked and with other material	Cows Buffaloes	Improvement in milk yield and fat%
Pods and seeds of Acacia and Prosopsis species	Soaked/cooked and with other material	Cows Buffaloes Goat	Improvement in milk yield, fat % also induce heat (oestrus?)
Bibba seed	As such or with concentrates	Cows Buffaloes	Induces of heat (oestrus signs?)
Tinosperma Cordifolia (creeper)	Green- both leaves and steam	Cows Buffaloes Goat	Increase milk production
Tree leaves Alanguim salvifolium, Bassia latifolia Butea monosperma	Green	Cows Buffaloes Goat	Increase milk production
Azadirachta indica	Green	Goat and others in dry season	Improves milk and serves as anthelmintic
Flowers of Bassia latifolia	Fresh or after drying	Cows Buffaloes Bullocks	Improves milk production, maintains body condition
Prosopis cinereria Leaves and pods	Fresh, also as leaf meal	Cows Buffaloes Goat	Helps to maintain production
Maize cobs and cotton bolls	Cooked with other material	Cows Buffaloes	Liked by animals cover maintains production

DISCUSSION

Below we describe some traditional practices regarding feeding of dairy animals, which are relevant for the discussions in this workshop.

Grazing practices and offering of roughage in the long form (unchopped).

In most parts of Gujarat, Rajasthan, Madhya Pradesh and Maharashtra the animals are sent out for grazing. This practice continues even in centres where cross-breds are produced. A closer look at the area indicated that a number of livestock owners do (generally) not send out lactating buffaloes for grazing. A possible explanation lies in the situations that existed in this area since a few centuries. The inhabitants never maintained high milk producing cattle, and the buffalo was the animal which produced milk most. The area had large areas under forest or grass land with sufficient grass, shrubs, creepers etc. available as feed resource for the animals. The cattle were mostly kept to produce bullocks, as a source of manure or fuel and as a mark of status. These animals could obtain sufficient nutrients from grazing, where they could select nutritious grass and legumes. Farmers also believe that some excercise is beneficial to the animal. The present day landholdings are small and priority is on grain production and not on fodder production. The animals still obtain the bulk of their feed from communal (grazing) resources and offered some dry fodder at night. Thus straw was not the major source of feed, since grazing was practiced. Feeding of the whole plant gives the animal a possibility for selection. It is known that, given a choice, the animal will naturally select more nutritious parts of the plant or plants species (Zemmelink, 1980; Wahed *et al.*, 1990; Powell, 1985). We also observed that the left overs are offered to unproductive or non working animals or buffaloes. This tradition is also further elaborated by the paper of de Wit *et al.* (1993).

Traditional processed and complete feeds

In some of the wheat and maize growing areas, interesting traditional practices have been observed of mixing feed material like wheat straw or maize crops with grains, cotton seed, cotton balls, forest produce like Acaceapods, tamarind fruit, alongwith salt. This mixture is not different from the complete feed which is now regarded as a "modern" concept in animal feeding. The mixture is completely soaked in the water and allowed to be heated for a few hours (sometimes overnight) with moderate heat, before being offered to the animal. This kind of processing might improve the palatability of the material and maybe the digestibility. The mixing of roughages and concentrate increases bulk and keeps the animal engaged during milking. These mixtures are being studied by laboratory evaluation.

Farmer's preference for feed materials

Preference for straw of certain varieties of cereals and preference for some tree leaves, tree seeds and weeds is reported from some areas. While discussing farmers' choice for certain varieties of sorghum and wheat it was reported that these are chosen not only for their grain quality, hardiness, resistance to drought, insect attack etc. but also for the fodder yield and quality. The field staff reported preference for straw of certain varieties of rice, and sorghum. Similar views have been expressed by Kelley *et al.* (1991), who have emphasized need for farmer surveys in crop improvement paying attention to straw yield and quality. The farmers' concept of straw quality is related to acceptability and intake of the animal. Laboratory studies to relate farmers' preference with scientific parameters are in progress. Investigation of reports from different tribal areas regarding beneficial effects of some weeds, creepers and tree leaves, on milk yield, fat percentage, conditions of the animal etc. are initiated. Anjan tree (*Hardwickia binnata*) investigated by the Agricultural University from Maharashtra is a case in point. Tree leaves preferred by farmers are from species like *Erythrina indria*, *Ailanthus excellsa*, *Delonix ellata*, etc. (Singh, 1984; Singh undated; Devendra, 1989).

Use of the mahuda flower

Mahuda indica (*Bassia latifolia*) is a common forest tree and the tribals are aware of its utility and would not cut the tree. The flowers that drop are gathered, stored and traditionally fed to bullocks before and during the cropping season, to provide bullocks with energy and resistance to disease. The explanation could be easy, since the flowers are known to be rich in starch. Also they are used as human food during scarcity and the flowers are fermented to make local alcoholic drinks.

The use of cotton seed, cotton seed cake and coconut cake

The use of cotton seed byproducts in the feeds for milk producing animals is known since generations. In some places the farmer persisted with the use of these materials in spite of contrary to recommendations by technical persons, availability of balanced concentrate and high cost of these materials (Rangnekar, 1993). We now know that these are superior protein sources. This is but one example where indigenous knowledge was not appreciated for quite some time.

FURTHER WORK

Information is gathered at selected centres to relate the feeding practice with the performance of different types of dairy animals with respect to milk production, reproduction and growth and at a few centres on working animals. This information, combined with traditional feeding practices and nutritive value of feed material used, would provide possibilities to develop practical to recommendations on animal feeding.

Training of farmers is a continuous activity in which feeding of animals, value of different feed material is a major subject. The discussions are now centered to obtain information on feed materials and feeding systems used traditionally by the farmers and incorparate changes if necessary. Feedback from farmers is invited and suggestions are made with regard to supplementation, conservation etc. keeping in mind the material familiar to these farmers. The staff has also made a start to pick up local words (for feeds etc.) from different regions, to improve communication with the farmers.

Studies to evaluate crop residues from rice, wheat and sorghum straw variety preferred by the farmers, have shown interesting results. The varieties preferred by farmers in most cases showing food composition and digestibility values. The work on to gathering of sufficient data continues.

CONCLUSIONS

The study taught us that one should neither dismiss offhand, nor get carried away by various beliefs, notions and practices. The practices followed by a large number of farmers are generally of useful nature and need consideration. Variable resource availability affect systems of farming and traditonal knowledge needs to be evaluated with care before changes can be suggested. Farmers are amenable to change and innovative. Many factors like communication, marketing, economics, government programs, socio-political leaders/organisations etc. do influence the practices. The farmers' resistance to change has a positive aspect also, particularly with regard to economically and socially backward groups which have no risk taking ability. Creating awareness of the usefulness and logic behind traditional farmers practices takes time, in the case for scientists, policy makers, or even field staff.

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RESEARCH FOR DEVELOPMENT ON CROP RESIDUE UTILIZATION (CONCLUDING COMMENTS AND SOME FAO EXPERIENCES)

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A major aspect of Research for Development is the importance to identify appropriate technologies which can be of benefit to as many small farmers as possible. The survey by BAIF presented during workshop demonstrates that small farmers often keep their animals better than larger farmers. The same observation was made recently in a UNDP project in Mauritius. It has also been established that small farmers contribute considerably to the supply of the milk market as mentioned by De Boer, as is well known from statistics and extensionists. Therefore, apart from the social aspects, the economic aspects also justify our interest in development of small farmers. The problem is that there are not so many suitable technologies available. It was indicated during this meeting that besides the lack of suitable messages, we have not always the mechanisms for extension of these technologies to the small farmers.

Based on FAO experience it is important to adopt an integrated approach, i.e., all problems encountered by the small farmer must be considered and a solution to these problems must be provided. For example, it is not enough to advise on straw treatment. The required inputs should be available, i.e. the farmer must have access to urea (at a good price), plastic sheets (if justified) and other supplements. It will probably be necessary to supply these inputs to the farmer in advance. To be able to recover the value of these inputs, a market should be available for the products, (which is easier with milk) and the advance could be deducted from the value of the sales. Veterinary services should also be provided when necessary, for preventive action and at the request of the farmer for curative measures. It is not possible to dissociate one production factor from the other.

Finally, the HUMAN factor is the most important. Training and support of the farmers is a must. Cooperatives, Development Boards, Farmers' Associations are the types of organizations that may provide these services. Research Workers and university teachers must cooperate closely with extensionists and farmers to identify the true problems of the small farmers. Research programs should be designed accordingly. By doing so, research will be more efficient, better adapted to the real needs and better recognizable for the farmers, because the farmers can make maximum use of their own resources and adapt the production systems to these resources.

Are we sure that the extension infrastructure is the weak point for the transfer of technology to the farmer? The problem may also be that the results of research are not adapted to the needs of the extensionists and the farmers. If better links are

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established, between research workers and farmers it will be easier to define appropriate technology and it will be easier for farmers to adopt the technology. To fill the gap between the laboratory and the farmer, more feeding/production trials are necessary to evaluate the response of the more on-farm trials/observations are required to assess the response of the farmer within his own farming system.

Rather than trying to maximize the individual performances of individual animals, feeding systems using locally available resources and maximizing their use should be developed. The approach which aims to satisfy the theoretical requirements of animals for maximum individual production has led to neglect the value of straw as a basal feed. Straw, in general, have a gross energy value comparable to that of grass as shown by Singh and Oosting in Session 2 in this workshop. It is necessary to make more of this energy available for the animal by

- improvement of the rumen ecosystem e.g. supplementation with NPN, minerals and vitamins;
- balancing the products of the ruminal fermentation e.g. with (bypass) nutrients, particularly protein;
- by treatment or processing to increase intake and digestibility.

The usefulness of each of these approaches needs to be considered per farming system.

In spite of the valuable efforts made, particularly at NDRI Karnal, biological treatments have not yet any scope for practical application at the farmers level (Session 3). On the other hand, the papers and discussions in Session 4 showed that urea treatment is a well established technology to improves the nutritive value of straw. There is less information concerning urea treatment of sorghum or maize stovers, but a good review was presented during this workshop by Prasad *et al.* (Part 4). The improvement due to treatment depends on the nutritive value of the original material. When the straw/fodder has a high initial digestibility, the effect and usefulness of treatment decreases. Treatment will only be advantageous if straws constitute the bulk of the basal diet.

While urea treatment has been successful in research stations and demonstration sites, and though practical technology is established, not many farmers have actually applied the method except in specific conditions. Various constraints have been identified in sessions IV and VI and the applicability depends on local conditions and on available resources.

There is an important variation within and between species and varieties in terms of straw quality and quantity. At equal grain yield it is obviously advisable to choose the variety which produces the best quality and/or the highest yield of straw. Genetic improvement of feeding quality of straw does not appear to be a promising venture, at least for rice it has been abandoned by IRRI. The usefulness of breeding or management for better more straw was fortunately also discussed in session V of this meeting.

Depending on the desired animal performance, it is necessary supplement untreated straw, i.e. nitrogen from NPN (urea), minerals (especially P and S) and vitamins, (e.g. with concentration or molasses-urea blocks). If no cheap supplements are available, proteins from (cottonseed) cake or fishmeal can be required, again depending on the desired level of production. For treated straw, or straw rations that are otherwise well supplemented there is no need for molasses-urea blocks. In both cases a small amount of good quality forage (such as fodder tree leaves) will be beneficial. Strategic supplementation, may give a dramatic responses in the case of animals which have been fed an unbalanced diet.

In the particular case of severe drought, which occurs rather often in certain regions of India, when feeds have to be transported, densification can be necessary. There is a need for economic studies of such processes and to develop machinery requiring low initial investment and low operating cost (energy). If it is not economically possible to develop such machinery, then densification will not be feasible. It is still more important and more appropriate to develop local feed resources which are tolerant to drought, such as fodder trees (*Prosopis* etc.).

Research for development must be directed towards and done together with the farmer, more specially the small farmer. Good research is not only what produces a nice paper for publication in a scientific journal, but good research is what solves a problem, and what is adopted by the farmer. Researchers should be evaluated and promoted on these criteria.

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LIST OF ABBREVIATIONS AND GLOSSARY

AAFARR	- Australian Asian Fibrous Agricultural Residues Research
ADAB	- Australian Development Assistance Bureau
ADF	- Acid Detergent Fibre
ADFD	- Acid Detergent Fiber Digestibility
ADG	- Average Daily Gain
ADIN	- Acid Detergent Insoluble Nitrogen
ADL	- Acid Detergent Lignin
AI	- Artificial Insemination
AIBP	- Agro Industrial By-Products
AICRP	- All India Coordinated Research Project
AMP/ADP/ATP	- Adenosine Mono/Di/Tri Phosphate
ANOVA	- Analysis Of Variance
AOAC	- Association of Official Analytical Methods
APO	- Asian Productivity Organisation
ARC	- Agricultural Research Council (U.K.)
ARDOM	- Apparently Rumen Degradable Organic Matter
ARNAB	- African Research Network for Agricultural By-Products
ATP	- Adenosine Tri-Phosphate
BAIF	- Bhartiya Agro Industrial Foundation
BAU	- Bangladesh Agricultural University
BIOCON	- Bioconversion project
BW	- Body Weight
CGIAR	- Consultative Group on International Agricultural Research
CIMMYT	- Centro Internacional de Mejoramiento de Maiz y Trigo
CP	- Crude Protein
CP_s, CP_t, CP_u	- Soluble, Total, Undigestible Crude Protein
CTVS	- Coconut Triangle Village System
CV	- Coefficient of Variation
CWD	- Cell Wall Digestibility
DANIDA	- Danish International Development Agency
DAS	- Department of Animal Science
DCND	- Dairy Cattle Nutrition Division of NDRI (Karnal)
DCP	- Digestible Crude Protein
DCWC	- Digestible Cell Wall Constituents
DDMI	- Digestible Dry Matter Intake
DGIS	- Directorate General for International Cooperation (The Netherlands)
Dig NDIN	- Digestible Neutral Detergent Insoluble Nitrogen
Dig UDN	- Digestible Undegradable Nitrogen (in the rumen)
DIP	- Degradable Protein Intake
DM	- Dry Matter
DMD	- Dry Matter Digestibility
DMI	- Dry Matter Intake
DNA	- Deosyribo Nucleic Acid
DNDF	- Digestible Neutral Detergent Fibre (=NDFD)
DOM	- Digestible Organic Matter
DOMI	- Digestible Organic Matter Intake
DOMR	- Rumen Degradable Digestible Organic Matter
DTAP	- Department of Tropical Animal Production
DUN	- Digestible Undegraded Nitrogen
DZS	- Dry Zone System
EEC	- European Economic Community
ERS	- Eastern Regional Station of NDRI
f_d, f_s, f_t	- potentially, soluble, after t hours of incubation in the rumen, degradable fraction
FAO	- Food and Agriculture Organization of the United Nations
FCM	- Fat Corrected Milk production (kg/day)
FICR	- Fibrous Crop Residues
FMS	- Fingermillet Straw
FS	- Farming System
FSR	- Farming Systems Research
FSR/D	- Farming Systems Research and Development
FSR/E	- Farming Systems Research and Extension
FTS	- Fungal Treated Straw

GCV - Genotypic Coefficient of Variation
GE - Gross Energy
GOI - Government of India
GN - Groundnut
GSO - Grassroots Support Organization
HCHO - Carbohydrate
HH - Household
HI - Harvest Index
HS - Hill Country System
HYV - High Yielding Variety
IAC - International Agriculture Centre
IARI - Indian Agricultural Research Institute
ICAR - Indian Council of Agricultural Research
ICARDA - International Center for Agricultural Research in the Dry Areas
ICDP - Intensive Cattle Development Project
ICRISAT - International Crop Research Institute for the Semi-Arid Tropics
IDP - International Development Program
IDRC - International Development Research Centre
IFS - International Foundation of Science
ILCA - International Livestock Centre for Africa
IRR - Internal Rate of Return
IRRI - International Rice Research Institute
ISNAR - International Service of National Agricultural Research
ISPA - Indo Swiss Project Andhra Pradesh
ITK - Indigenous Technical Knowledge
IUP - Indigestible Undegradable Protein
IVDMD - *In Vitro* Dry Matter Digestibility
IVNDFD - *In Vitro* cell wall digestibility
IVOMD - *In Vitro* Organic Matter Digestibility
IVRD - *In Vitro* Rumen Digestibility
k_d - fractional rate of digestion
k_d' - k_d * fraction of potentially degradable particles in the rumen
k_i - fractional rate of intake
k_p - fractional rate of passage
k_p' - k_p * fraction of small particles in the rumen particle pool
LCRF - Least Cost Ration Formulation.
LL - *Leucaena* Leaf
LP - Linear Programming
LSD - Least Significant Differences
LW - Live Weight
LWG - Live Weight Gain
MBP - Microbial Biomass Protein
ME - Metabolisable Energy
MED - Man Equivalent Days
MFN - Metabolic Faecal Nitrogen
MJ - Megajoule (equals 10^6 Joule)
MOTAD - Minimization Of Total Absolute Deviations
MPAU - Mahatma Phule Agricultural University
MVS - Mid Country Village System
MW - Metabolic Weight
N - Nitrogen
NADN - Non Ammonia Degradable Nitrogen
NAN - Non Ammonia Nitrogen
NANUN - Non Ammonia Nitrogen Undegradable Nitrogen
NARP - National Agricultural Research Project
NBDMD - Nylon Bag Dry Matter Digestibility
NBNDFD - Nylon Bag Digestible cell wall content
NBOMD - Nylon Bag Organic Matter Digestibility
NCFR - Non-conventional Feed Resources
NDF - Neutral Detergent Fibre (also called cell wall, or cell wall concents)
NDFD - Neutral Detergent Fibre Digestibility (=DNDF)
NDFI - Neutral Detergent Fibre Intake
NDIN - Neutral Detergent Insoluble Nitrogen
NDRI - National Dairy Research Institute