4.6.1. UREA TREATMENT OF STRAW

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INTRODUCTION

Urea treatment of straws is thus far the only chemical treatment with practical potential for farmers' conditions. Urea is available in many parts of the country; it is a relatively safe chemical that is easy to store and also easy to dissolve in water. Urea treatment can be done in different ways, depending on the local conditions and preferences, but some rules can be given regarding concentration of urea, duration of treatment, amount of water to be used and way of stacking. Of all treatments, the economics and feasibility of urea treatment is best understood. Though on a limited scale, urea treatment is done by farmers under practical conditions in different places of the country. All these aspects will be covered in this chapter, and some attention is given to aspects of animal health in relation to feeding of urea treated straw.

Handbook for Straw Feeding Systems
Kiran Singh and J.B. Schiere (eds.), 1995
ICAR, New Delhi, India

UREA AS A CHEMICAL

Urea is a white crystalline solid organic compound, widely used as a nitrogen fertilizer. Pure urea has a nitrogen concentration of 46.6 percent, equivalent to a crude protein content of 290 grams per 100 gram of urea since protein itself has only 16% nitrogen. Urea is easily broken down to ammonia by the urease enzyme that is produced by soil or rumen microorganisms in the following way:

$$\begin{array}{l} NH_2 \\ / \\ C = O \\ \backslash \\ NH_2 \end{array} + H_2O \text{ ----> } 2NH_3 + CO_2$$

As an NPN-source urea can replace part of the dietary protein in the ruminant diet. Rumen microorganisms first break down urea to ammonia, which then serves as a nitrogen source for the production of microbial protein, ultimately serving as a protein source for the host ruminant (#4.3.1.).

Urea, when used for treatment of straw enhances the nutritional quality of straw in terms of increased nitrogen content, improved palatability and digestibility of straw. During the treatment process, ammonia is generated from urea, and in the presence of water it forms the alkali named ammonium hydroxide. It has been well-established that alkali treatment makes the cell walls better available for fermentation in the rumen. In temperate climates, anhydrous (gaseous) ammonia or aqueous ammonia (ammonia dissolved in water) is used for the ammoniation of straw. In warmer climates the urea

treatment is more feasible because of the easy availability of urea and its quick breakdown into ammonia compounds under higher ambient temperatures.

FACTORS AFFECTING THE PROCESS

Various factors affect the ammoniation process during the urea treatment, ultimately determining the nutritional quality of the treated straw. None of these factors is very critical, but some rules can be given.

Urea concentration

An amount of 4 kg of urea (equivalent to 2.2% ammonia) to treat 100 kg of air dry straw has been found to be an optimum level. Levels lower than 3.5 kg may not produce sufficient ammonia for effective treatment, and levels above 4 kg have not further increased straw quality. Higher levels result in higher digestibility in *in vitro* trials. In practical *in vivo* work however, where it is the combination of increased digestibility and intake that counts, no beneficial effect of higher urea levels is found. A farmer can weigh the 4 kg of urea in a bucket or a cup once, mark the level and subsequently use that measure for further weighing.

Water requirement

The moisture level is not very critical to the process, provided it is not too low. When water availability is a problem, e.g. in arid regions or dry seasons, water usage needs to be minimized. Water however is essential because it helps hydrolysis of urea. It is also required to form the alkali and to act as a vehicle for the ammonia to penetrate the cell walls. A 30-40%

water level has been shown to get the desired effect. For achieving this, 50-60 litres of water can be used to dissolve 4 kg of urea and to spray it over a layer of 100 kg of air-dried straw. A number of straw bundles can be counted to know how many are required to make 100 kg of straw. With chopped wheat straw, the number of baskets required to form 100 kg of straw can be counted. With regard to water measurement, milk cans of 25 kg capacity can be filled with water twice to dissolve 4 kg of urea. In absence of milk cans or any other of these measurement procedures, it is possible to develop locally applicable methods, perhaps more adjusted to the amount and type of straw to be used.

Methods of spraying

For spraying of the urea solution over a layer of 100 kg straw or whatever quantity that is chosen, a gardener's sprinkler can be used to achieve uniformity in urea solution coming in contact with straw. Use of a broom and a bucket has also been found to be effective to spread the water. For chopped wheat straw, some hand mixing after the spray of urea solution is desirable.

Compactness of the stack

Once a layer of 100 kg has been treated, an additional layer of 100 kg is placed on top and sprayed with urea. This process is repeated to make a stack. A compact stack has two advantages. Firstly, the effectiveness of the ammoniation process is better. Secondly, there are less chances of mould growth which leads to spoilage of the straw. Chopped wheat straw compacts very well during stack making. Such a compactness cannot be achieved so easily in loose rice straw, though bundles are better than loose unchopped

rice straw. It may be important to know that particularly in the Northern wheat belt the straw comes in chopped form, in other areas, e.g. West Bengal, it is the wheat straw that remains unchopped (#5.2.).

Duration of treatment

Since the temperature of the heap affects the rate of hydrolysis of urea to ammonia, the duration of treatment can be variable, depending on the region or season where the treatment is done (see Box 1).

Box 1. Relation between outside temperature with required treatment time.

In Norway, the outside temperature is reported to affect the ammonia treatment time as follows:

Outside temperature (°C)	Treatment time (weeks)
Below 5	more than 8
5-15	4-8
15-30	1-4
above 30	less than 1

The effect of outside temperature on treatment time with urea is a bit unclear, but urea treatment is not well possible in colder countries/regions with snow and frost like Scandinavia or Scotland and probably neither in the Himalayas or other mountain ranges in the tropics. Usually however the temperature inside the stack is higher than the outside temperature, due to microbial action and/or chemical reactions between urea, water, ammonia and straw. And since it is ultimately the stack temperature that determines the reaction process, it appears critical that the initial temperature is high enough to get the process started. In practice it appears that when straw is treated under conditions with an ambient temperature of around 20°C (during day time), the inside temperature in a urea treated straw stack can be as high as 50-60°C in 1-2 days. In that case the outside temperature is irrelevant to what happens in the stack. Bigger stacks or heaps can control temperature better than smaller heaps.

Source: Sundstol *et al.*, 1978; Tharmarajah and Van Der Hoek, 1986

Ammoniation periods of seven days or less are shown to be sufficient under tropical conditions, as found in Sri Lanka and Southern parts of India. The duration of the treatment can also be decided upon, by considering the local conditions as well as the scale of the treatment. Smaller quantities can be treated on a weekly basis, requiring less labour at once, becoming part of the routine animal feeding practices. In certain farming systems however, especially in northern India, straw is stored in large stacks for many months. In such situations some farmers wish to treat straw with urea at the time of stacking right after harvest, though it involves more labour at that time. Thus, also the duration of the treatment becomes longer. A period of at least two to three weeks has been suggested to be necessary for the treatment of straw in the North, during the winter months, when the ambient temperature is lower. A note of caution however: *longer periods of storage (> three weeks) increase the risk of spoilage by mould growth, especially when the straw is too wet.*

Type of crop residue used

The type of crop residue used and its initial nutritional quality affects the effectiveness of treatment. The poorer the initial quality of the straw or stover, the higher the effect of treatment, possibly because better quality straws have more cell solubles and lower fibre content, the latter actually getting the benefit of ammoniation (#3.3.). Stovers, i.e. coarse straws have generally a higher initial nutritional quality than slender stemmed straws, and they will benefit less from treatment. Furthermore, if mouldy straw is used for the treatment, one can only expect a reduction, rather than an improvement in the quality of straw.

Storage method

A key factor which determines economics and practicability of the urea treatment of straw is the use of storage structures for the treatment. Farmers generally prefer storage methods based on existing traditions, but new ways are found acceptable depending on their cost.

Covering of the stack is important, though particularly the larger, and more densely packed stacks could be open, i.e. covered with only a layer of untreated straw. sealing can be done with materials like polythene, coconut leaves, banana leaves, or empty urea bags stitched together. Farmers also use various storage structures like earthen pits, lined and covered with banana or coconut leaves, wooden or cemented clamps, cemented silos, rings or pipes (Fig. 1). Apart from that, urea sprayed straw can also be packed in sacks made from polythene or by stitching empty straw bags. All these methods have been used in Bangladesh, Sri Lanka and parts of India. No hard and fast rule can be given and local farmers' preference is to be the best guide in this. Particularly when small heaps are treated it becomes important to have the stack adequately sealed.

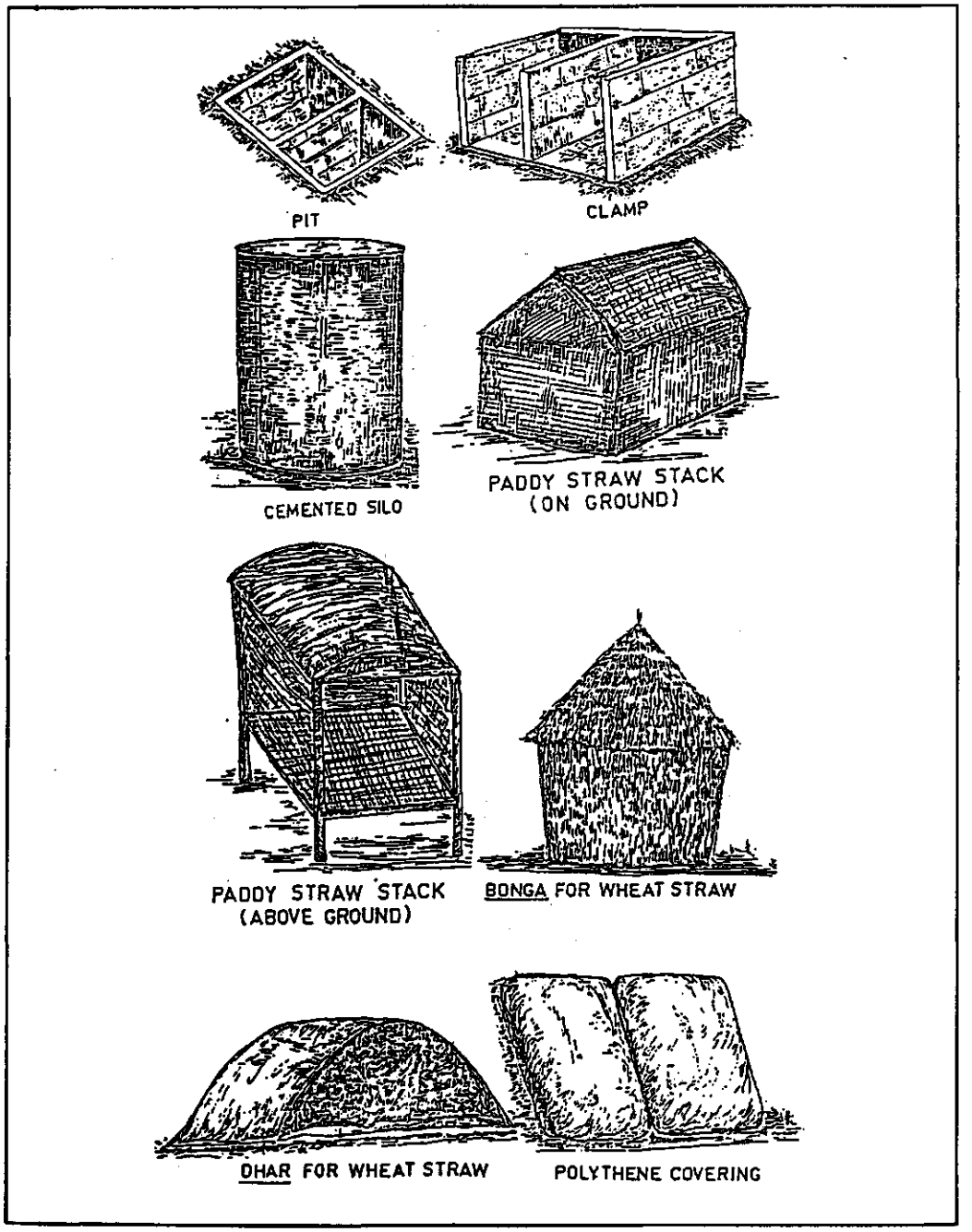
In Bangladesh, earthen pits or bamboo baskets lined with banana leaves and covered with jute bags, plastered with mud and cow dung have been used during the urea treatment of paddy straw. The pit system, i.e., a hole in the ground, carries the risk of contamination with soil or seepage of rain water through the sides. Loading and unloading of pit is also difficult, and the digging of pits can be a problem in rocky soil. Long straws like rice in Northern India and finger millet and sorghum in Southern India are stored in stacks, whereas chopped straw or 'bhoosa' wheat is stored either in a

room, a 'bonga' or a 'dhar'. Both the 'bonga' and the 'dhar' provide air tight conditions, the latter after mud and/or cow dung plastering. Farmers make 'dhars' essentially to save time, i.e. to allow rapid storage in the field, accepting higher losses of straw in this system than in the 'bonga'.

For a continuous supply of treated straw, a twin pit or clamp systems can be suitable. The size of the clamp depends on the amount of straw to be fed from one clamp (or stack) and on the density of the straw (70-120 kg straw/m^3). Such a clamp (wooden or cemented) is suitable for small dairy owners or landless labourers with a few animals, who treat the straw with the help of family labour on a weekly basis.

The different methods of stacking or storing urea sprayed straw have their relative merits and demerits, but the bottom line about all these methods is that the better the compaction and airtightness of the stack, the better will be the quality of the treated straw. Finally, the farmer has to decide according his/her own preference.

Figure 1. Different storage structures for straw treatment (for explanation of twin pits see text).



Note: a wire mesh can also be used to keep the straw together and to assist compaction.
Source: Rai et al. 1993

EFFECT OF TREATMENT ON STRAW QUALITY

Much work has been done by now to consistently show that treatment improves straw quality in term of digestibility and intake. Also farmers have confirmed that feeding of treated straw positively affects animal production and health.

Nutritive value: scientists' perceptions

Urea treatment improves digestibility, intake and crude protein content of the straw. The extent of response to urea treatment in terms of straw quality is variable, due to variation in initial straw quality, species difference among straws and stovers, and the type of animals used for the experiments. A summary of the effect of urea treatment on the quality of slender and coarse straws, and an average for a number of straw types is given in Table 1.

The increase in crude protein content caused by urea treatment is in the order of 4 to 5 percentage units, due to the addition of ammonia. Crude protein content increases are higher than what would be required in relation to the increased digestible energy availability in the rumen. The higher digestibility and intake is mainly caused by the increased rate and extent of cell wall degradation.

Table 1. The "scientists" perception of the effect of urea treatment on straw quality.

Type of Straw	US/TS	DMI*	DDMI*	DOMI**	DMD	OMD	IVOMD
Rice	US	52-84	35-38	0.86	42-43	47-52	44-47
	TS	64-115	50-76	1.36	44-60	57-61	51-83
Wheat	US	63-64	-	-	39-40	40-41	-
	TS	71-81	-	-	42-50	43-53	-
Barley	US	40	-	-	49	-	-
	TS	53	-	-	65	-	-
Finger millet	US	48-65	32	-	49-52	51-55	-
	TS	60-87	52	-	60-69	63-72	-
Sorghum	US	51	27	-	50	55	-
	TS	94	41	-	55	59	-
Maize	US	3.31***	-	-	57	-	-
	TS	4.09*	-	-	62	-	-

Notes: * $g/kg^{0.75}$
** kg per 100 kg BW
*** kg per day
Abbreviations: US is untreated straw;
TS is treated straw;
DMI is dry matter intake;
DDMI is digestible dry matter intake;
DOMI is digestible organic matter intake;
DMD is dry matter digestibility (in %);
OMD is organic matter digestibility (in %);
IVOMD is in vitro organic matter digestibility (in %).
Source: Prasad *et al.*, (1993)

Animal response and health

The effect of treatment on animal response is more difficult to give. this is because of the variety of animal species and type of produce, and also because farmers often feed less supplements after starting to feed treated

straw. Generally, it can be said that by replacing a large amount of US by TS in the ration:

- the butterfat tends to increase with a few decimal points;
- milk yield increases of 0-1.5 litres are reported, but 0.5-1 litres appears to be a reasonable range depending on other feeds fed, stage of lactation and body weight of the animal;
- animals of 100-150 kg body weight will lose 50-100 g/day if fed on only US, whereas they will gain 50-100 g/day when fed on TS alone;
- a milk yield of 2-4 litres on TS alone seems to be possible, of course depending on the quality of straw and the bodyweight of the animal.

All these values have to take into account the animal's body weight, the quality of the straw and the other components of the ration.

Health and reproduction

To assess the effect of urea treated straw on animal health one has to take into account with which ration it is to be compared. As a rule it should be remembered that both urea and straw are compounds that are well known and natural to the animals body, so no harm is likely (#4.3.1.). When TS feeding is compared with feeding of US it can be said that:

- fertility and reproduction remains the same or improves;
- in some cases, the dung gets slightly stickier. No negative health aspect is ascribed to that, but (women) farmers may find it more difficult to clean the animal or to make dung cakes;
- no negative residues of straw treatment are known to enter the milk. The use of pesticides and herbicides should not be overlooked however, though some are reported to be denaturated in alkaline environment, and the problem is not confined to the use of treated straw alone;

- provided the straw is not mouldy, there are no reported cases of more mycotoxins due to treatment. In fact, NH_3 is known to inactivate mycotoxins;
- high levels of NH_3 are supposed to occur in the rumen, due to feeding of treated straw, but it is unlikely that they exceed those due occurring for example in berseem feeding. Excessive NH_3 levels in the rumen may depress the absorption of Mg (#4.3.2.), but in practice no problems are known to have occurred;
- a condition termed "bovine bonkers" occurs under a combination of heat, high sugar content and use of ammonia (NH_3) for treatment. It is not known to occur with urea treatment of straw;
- urea toxicity due to feeding of urea treated straw is unlikely or even impossible, because urea and straw are well mixed and the intake of straw is slow (#4.3.1.);
- fungal growth in straw can produce mycotoxins that cause abortion or other ill effects. Fortunately, ammonia produced during treating straw with urea can serve as preservative to prevent mould growth;
- Vitamin A deficiency in treated and untreated straw can cause fertility problems in cows, but this can be prevented by including some green fodder in the ration.

Farmers' perceptions on urea treatment

Many field demonstrations and on-farm trials have been conducted with treatment technology. The feedback collected from farmers who feed the treated straw to their animals suggest that the response has been generally positive, though not always sufficient for most farmers (see Box 2). Farmers report that by feeding treated straw:

- straw consumption increases;
- a better growth performance is observed;
- health improves, i.e. a shiny skin is observed;
- an increase in milk yield ranging from 0.5 1 - 1.5 litres per animal per day;
- butterfat remains the same or increases slightly.

Some farmers have been able to reduce the quantity of concentrate fed to the animals, thereby reducing the cost of production if straw is cheap compared to concentrate. The other advantages of treatment are less wastage of feed and less need to chop the straw.

Box 2. Perceptions of a few women farmers on the treatment of straw with urea in Haryana.

Interview questions	Replies of landholding woman farmer	Replies of landless woman farmer
Have you been involved in the treatment of straw and the preparation of the stack?	Yes.	Yes.
Did your husband discuss the treatment with you, before he agreed to join this trial?	It was a mutual decision.	I was the first one to be approached, but I send for her husband who was in the field and together we agreed.
Which tasks did you perform during the treatment?	Carrying water. Preparing the urea solution.	Arranging the straw bundles. Preparing the urea solution. Trampling the stack. Pumping water into the hose.
Was it difficult work?	No, not at all.	No, very easy.
Was the work dirty or inconvenient?	No.	No.
What are your experiences with the treated straw?	Positive, the milk yield increase a 1/2 kg of milk per day.	Positive. A high increase in milk production, the buffalo from 6 to 8 kg milk, the CB cow from 2,5 to 4 kg increase.

Do the cattle like to eat it?	Yes, first it smells and for a few minutes they do not eat it, then they eat 11 kg instead of 7 kg.	Yes, they eat more.
Which cows were fed the treated straw?	One lactating desi cow and one young cross bred.	One lactating cross bred cow and one buffalo.
Is chaffing easy?	Yes, easier.	Yes, easier, there is no dust because it is wet.
Is the feeding more work?	Not really.	Yes, they eat more, but that does not matter.
Do you process the milk, and is the quality of the milk different?	I make ghee and the fat percentage increased, so there is more ghee; I make dahi (curd) which is tastier.	I make dahi, which is first class, and the milk is also fine.
Is the dung different?	Dung is fine.	It is more work to clean the floor, because the dung is sticky.
Would you like to treat straw again, even if the men don't want to help?	We will convince them, but the money for the urea is a constraint.	I will do it again, even if I have to buy the urea myself.
Do you feed less concentrates now?	Before I gave ready mixed concentrates, now only the treated straw and berseem.	Straw and mustard cake, not much less.
Is this a large farm?	No, a small farm, 0,3 ha, and husband has a job.	No, landless, just 0,5 ha leased land; straw is obtained for free.
Who sells the milk? And to whom?	Milk is for home consumption of 4 persons.	The milk is sold to a vendor, who pays in advance once a month. The husband is the major decision maker on the sale and the income.
Source: adapted from J.G. Muylwijk, BIOCON, consultancy report, Sept. 1994.		

Despite these beneficial effects observed by farmers, the continued use of urea treatment after initial demonstration has been disappointing due to constraints like:

- sticky lung produced by the animals, complicating the (women's) job of

preparing dung cakes;
- pungent smell from ammonia;
- fear of fungal spoilage of straw in open stacks;
- where the straw availability is limited, some farmers get discouraged because the stacks of straw get exhausted quickly.

The most important consideration for farmers not to take up this technology is that in most cases the returns are marginal. The suitability of urea treatment in different Farming Systems is now reasonably well understood. From all experiences in on-farm trials and economic calculations it appears safe to suggest that this technology is most likely to work under the following situations:

- when plenty of dry straw is available, free from fungal contaminations;
- where farmers have slender straws from rice, wheat and barley rather than coarse straws;
- when straw is cheap, and available in plenty relative to other feeds, i.e. the straw should be cheap compared to other feeds;
- when there is a shortage of grasses or other green feed;
- when water is freely and conveniently available;
- when the price of urea is not prohibitive;
- cost of polythene covering material should be low;
- labour availability should be good, though small stacks require not as high labour inputs at one time as the large stacks;
- space for storage of treated straw should be available;
- when the animals are low to medium producers (milk or meat);
- a ready market for milk or meat should be available. In other words, the produce should be sold at a remunerative price, allowing the purchase of the inputs.

It should be noted that when the availability of straw is high, it implies that its price is low, the same is true for labour availability and the price of concentrate or the cost of grass.

In principle, both large and small farmers can apply treatment. For poor and marginal farmers, the cost of the inputs like urea and polythene could be a constraint in the use of this technology. For larger dairy farmers, the availability of straw and labour may be a problem, or the production of the animals may be too high to have large amounts of (treated) straw in the ration. For some small farmers, grasses are available at low cost or even free by sending the animals for grazing on roadside and wastelands. This deters them from adopting a technology which costs money. In rainfed and arid zones, water availability can be a limitation to take up this technology.

More factors can be considered. The priority that many farms families put on crop production affects livestock production as a whole, particularly in cash crop areas. A crop farmer who purchases urea on credit or other limited resources, prefers to use the urea on cash crops rather than for the treatment of straw, where the returns are low and marginal. In Northern India, immediately after the paddy harvest farmers get busy in preparing the land for the wheat crop and they do not have time for storage or treatment of straw. Nor do they need treated straw because greens become rapidly available in that season. In order to avoid labour problems, some farmers, e.g. in Sri Lanka and Southern India prefer to treat the straw in small batches of 50-100 kg in pits or cemented rings or clamps, or even polythene bags. Large farmers in Northern India use combine harvesters for the harvest of wheat and paddy, since the cutting height is higher, long stubbles

are left in the field, which are simply burned before preparing the field for the next crop. Many farmers also keep a portion of their land for the cultivation of fodder crops and they feed wheat straw rather than paddy straw. There are farmers who on the other hand actively engage in commercial milk production but who possess insufficient greens. Such farmers can apply urea treatment of wheat and paddy straw. However, when the individual animal output is high, and when concentrate is relative cheap, substitutional supplementation becomes more attractive than treatment of straw (#4.3.).

CONCLUSION

Urea treatment improves the nutritive value of straws, in terms of total content, energy digestibility and intake. The crude protein content is also increased but beyond what is needed! Farmers have confirmed these technical results in practical conditions. The effectiveness of the treatment depends on factors such as type of straw, concentration of urea, moisture level, environmental temperature, method of spraying, compaction and duration of the treatment and the method of storage. Some of these factors are governed by local conditions. The technology is technically feasible, yet in practice many farmers feel constrained to adopt the method. The most important constraints are probably the marginal returns from the technology, the non-availability of sufficient straw, urea, or too high levels of animal produce. It is well established however, that the technology can be adopted where:

- grasses or other green fodder are not available;
- straw is cheap and readily available;

- concentrates are relatively expensive;
- water is freely available;
- there is a ready market for milk, fetching good prices to the farmer.

Health hazards of feeding urea treated straw are unlikely. Deficiencies of minerals and vitamin A which can cause fertility problems can be easily overcome by supplementation, and they are due to the feeding of straw, not to the treatment.

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