Selection of technology for food processing in developing countries

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Foreword

ICFSN (International Course in Food Science and Nutrition) organises diploma courses for graduates in mid-career from developing countries. These courses of five months duration are held in Wageningen, The Netherlands. Each course has a specific theme of particular relevance to the development of food science and human nutrition in these countries. In addition to running these courses, the core staff are actively involved in training programmes in co-operation with various institutions in developing countries, consultancy services, and the publication of related material. One such publication is this book which arises from a felt need to publish the lectures and other material prepared for two recent courses on rural food technology. It has been written for those concerned with the development of the agro-industrial sector, particularly those involved in training and those working in this sector. Although the basic principles underlying the proper choice of technology are generally applicable, this book is directed especially to the problems of the developing world.

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1 Introduction

Food Processing activities in developing countries must increase to maintain the food supply for the growing populations. Despite recent improvements in crop yields, demand still exceeds supply in many areas. This problem must be overcome by concerted action to increase the amount of food produced and to reduce the losses between harvesting and consumption. It is the role of the food processing sector to ensure that these losses are minimised and that the consumer can obtain products of the desired quality in adequate amounts.

Industries can also provide much needed employment. Most large-scale food factories are designed to operate with a very small staff, and can only be justified in areas where manpower is scarce, or where more useful and profitable employment is available. Labour-intensive industries based on traditional technology are often more suited to prevailing social and economic circumstances than industries using imported large-scale processes. The product quality however is usually only acceptable to local purchasers. Goods for exports must be manufactured in purpose-built plants. For many foods there is a spectrum of processing operations from traditional household preparation to large-scale industrial production.

Various authors (Stewart, 1977; ILO, 1978; Baron, 1980) have made fairly detailed economic studies of food industries in developing countries. Their approach stresses the employment provided by industry and its profitability. Less weight is put on the technological suitability and the socio-economic and cultural consequences of an industry. This book presents a consolidated approach to select the most suitable technology for a given situation and places an equal emphasis on all factors affecting this choice.

The authors perceived the need for this text in the course of their lecturing activities in the International Course for Food Science and Nutrition in Wageningen and during field work in various developing countries. It is based on experiences gained developing and teaching this course and implicitly contained suggestions for curricula at other institutions. It is however not a textbook for a course although it contains a brief coverage of the technical, economic, social and other scientific disciplines that have a direct relation to the problems of food processors.

The book is aimed at those involved in planning and developing food processing industry. This includes food processors but also people in a position to advise processors and, in co-operation with them, make decisions about the future of an industry. These people may not have an education in food technology, but in their jobs as economists, nutritionists and agronomists in developing projects, they may encounter problems associated with the processing of foods. They should be aware of the information available from the various disciplines concerned so that if necessary a specialist's opinion can be sought.

The impacts of a new technology on society can be so diverse that there are many factors to be considered before making any decision for a change. Decision making can be rationalised by the use of a generally applicable scheme.

Any attempt to solve a food associated problem must conform to the guidelines of the national development strategy. This policy can only be defined after detailed consideration of the relative importance of factors such as generating new employment and conserving the existing social structure or earning foreign currency and becoming more self-sufficient. The level of social, economic and industrial development however can vary so much within one country that any one project should only consider the problems of a well defined section of the population: 'the target group'.

A programme is likely to be composed of several projects, each designed to tackle different needs of the various target groups. Equipment and processes can then be tailored to their needs. This is achieved by a close interaction between people concerned with decision making and extension and the target group during all stages of the development project. In this way the development workers can obtain detailed information on the quality standards for the food and its by-products, the suitability of certain types of equipment, the social structure of the target group and a variety of other factors that have a direct bearing on the selection and adoption of new processes. The target population in turn will receive advice on how the new technology functions, what maintenance it requires and what advantages it offers over previous methods.

A detailed comparison of different processing technologies for three important commodities, sugar cane, maize and cassava clearly shows that in practice a compromise must be made between their desirable and less acceptable social and economic consequences.

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2 Development and technology

2.1 TOWARDS PLANNED DEVELOPMENT

Technological development and the development of society as a whole are closely related. Technological advancement first arose from the need to increase productivity. The first tools, for example were developed by human beings to improve and ensure their food production. Efficiency in the utilization of energy and raw materials was, and is, a second important reason. The desire for consumption goods that make life easier or more comfortable also stimulates technological development. As a definition of technology Müller (1976) suggests that technology consists of four different elements, strongly related to each other:

- knowledge (science, education, skills, know-how)
- organisation (institutional aspects of methods of production, co-ordination, relationship to the environment)
- technique (method of production or production process, the combination of man-material-tool)
- result (product)

In the process of development, transfer of technology plays an essential role. This transfer has occurred and occurs in many cases as the result of numerous individual actions without any intentional planning. Chinese earthenware for instance reaching East Africa through existing trade channels was used there centuries ago without any direct contact of African and Chinese people. In more recent times however transfer of technology is often more planned.

During and after colonial times the transfer of technology was particularly directed towards the production of raw materials for European industry. It was generally thought during this period that plantation scale production systems with primary processing factories based on European technology best served this purpose. It can be contended that one of the main incentives for colonialisation was the search for new sources of raw materials.

From the Second World War onwards the whole picture changed rapidly. The western world went through a fast technological development, most former colonies became independent and planned development and development aid were introduced. In most cases the governments of the so-called 'developing countries' were taken over by people who had received their education during colonial days. These governments considered that problems of infrastructure, food and industrial production could best be solved by national planning. Large scale projects were implemented and nationwide programmes proposed which utilised modern technology developed in western countries. This strategy is termed the 'modernisation approach'.

2.2 MODERNISATION APPROACH

As a development philosophy the modernisation approach is characterised by an emphasis on large scale production, mechanisation in agriculture and capital intensive industrial operations. This approach requires a large initial investment and aims to give a high productivity of labour and capital. Technologies and equipment are usually developed and constructed in industrialised countries or licensed from foreign companies.

Modernisation of agriculture initially benefits in particular those farmers able to risk investment capital in an attempt to improve yields by using sophisticated equipment or innovative techniques. The modern industries that are established produce foods and other products that are often destined for the urban high income consumer or for export.

In the modernisation approach it is expected that the rapid development of the economy on a national level will automatically lead to the development of all levels of society. In other words, development is assumed to 'diffuse' or 'trickle down' spontaneously. Stimulation of progressive farmers is expected to lead to an improvement in crop yields on their farms, and to surplusses of agricultural produce. This allows the creation of a modern food processing industry which in turn creates a market for the produce from small farms. The success of these enterprises should encourage smaller industries to expand.

Often the larger modern food industries are branches of transnational companies. In the view of one transnational company (Orr, 1976) their contribution to the development of a national economy can be substantial. Through their activities, available raw materials are exploited and managers are recruited and trained locally. The country's dependence on external sources of food and trained personnel is reduced and local (supply) industries are stimulated (import substitution).

This may all be true, but it does not explain which part of the population benefits most from such a development.

2.2.1 The 'dual economy'

In virtually all developing countries, attempts at rapid modernisation led to an increased inequality in the distribution of income, food availability and employment opportunities. The green revolution in India, for instance, brought an increase in cereal production, but only the wealthy landowners benefited financially from the higher crop yields. This development led to a further strengthening of the so-called 'dual economy' that had already started to develop in the colonial period.

A dual economy is characterized by the existence of two distinct sectors in the economy, which may be termed the 'modern' sector and the 'traditional' sector (Scott, 1973; Brunsveld, 1980). For agriculture and agro-based activities this is shown in a simplified form in Figure 1. 'Traditional' is used here to describe the 'non-modern' sector (society), which includes agricultural production, small traders and craftsmen. Small industry which uses not only traditional but also improved traditional and intermediate technologies falls within this 'traditional' or 'informal' sector.

The modern sector is represented on the right of Figure 1. This sector is characterized by a market oriented production using mostly larger scale, capital intensive technologies. Relatively few people find employment, but they are usually more

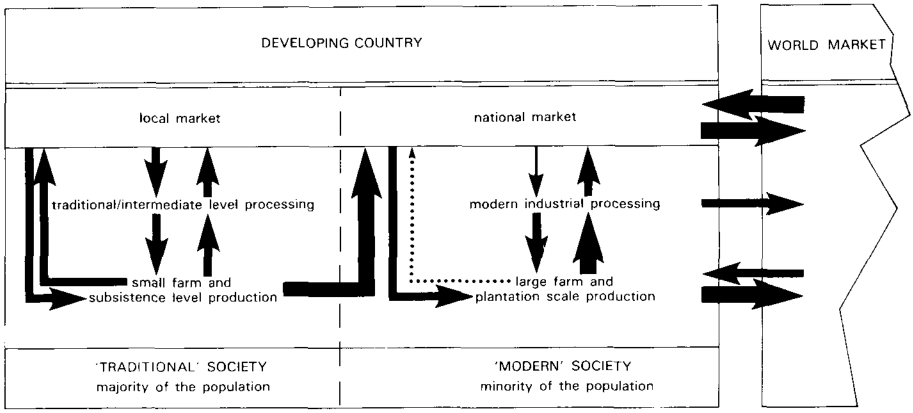

Fig. 1. 'Dual Economy' and some of its interrelations. (from Brunsveld, 1980) The relative importance of trade relations is indicated in increasing order by the thickness of the arrows.

educated and skilled than those in the traditional sector. Most of the cash flow circulates in this sector and most of its products are exported, sometimes after processing. When sold in the local market, products may be too highly priced for the majority of the population, while others compete with products of the informal sector. Luxury consumption articles produced (for instance) under licence from a foreign company will be too expensive for most people. However, advertisements for these products often refer to status or health and many people are motivated to buy such articles, although they require a relatively large proportion of their income. This is the case with milk. In many countries the production costs for one litre of milk are about 15% of the average daily wage (Bachmann, 1979).

The traditional or informal sector (Fig. 1, left part) employs the majority of the population, and is found in rural as well as urban areas. It involves traditional as well as improved traditional technologies and adapted or scaled-down industrial processes. The agricultural production within this sector is mainly for subsistence use. A large part of the market oriented agricultural production is exported indirectly, sometimes after processing, to the world market for raw materials via private traders or a national marketing board. Food processing and other manufacturing activities take place in the household or in small industries producing for the local market.

2.2.2 Criticism on the modernisation approach

Modernisation has sometimes brought impressive achievements. Infrastructures have been developed, foreign exchange earning increased, food production improved and a growth in gross national income recorded. As already mentioned however, it leads also to a lagging behind of large parts of the population and to unbalanced and unstable societies.

There are various reasons for this failure of the modernisation approach to create stable societies of which the most important are:

- It refers to general national criteria for development and fails to consider the specific interests of different sections of society.
- The expected 'trickle down' effect does in practice only occur to a very limited extend.

Although a dual economy is the inevitable consequence of a modernisation policy, some of its side-effects could be reduced by the use of profits from industry. Frequently, however, these industries are not as profitable as originally expected. What reasons can be found for this failure.

Perhaps the most common problem of large scale imported plant is that they usually operate with excess capacity. In West Africa, for instance, most food industries run at below 50% of their maximum capacity. The reasons for this can be:

- a lack of raw materials
- irregular delivery of raw materials
- an inadequate supply of spare parts
- poor availability of skilled labour and management
- unreliable energy services and other utilities
- overestimation of the market for the product
- insufficient insight into local quality standards.

Processes, developed for situations where labour costs are high but capital costs low, can lead to the displacement of labour by capital. Unemployment may result if no alternative work is provided. There are many examples of this effect, such as the loss of livelihood suffered by artisan shoemakers after the importation of machines for the mass-production of plastic sandals and shoes (Marsden, 1970). Or the introduction in India of large fishing and fish processing vessels which caused a depletion of fish stocks with the result that traditional fishermen lost part of their income. The diet of the coastal population was also influenced because an important low-cost protein source was no longer available (Alvarez, 1979). If workers are necessary for other activities then the introduction of labour-saving technology may be worthwhile, but in general, one should be very cautious about the social acceptability of labour displacements.

The use of imported technologies may also cause problems in the socio-cultural field. The differences in habits and values between the area where a technology originated and that where it is applied should be appreciated. In many developing countries social relations are much more person than task-oriented. Baranson (1969) reports:

"Factory organization based upon kinship and personal relations, rather than ability and productivity, can undermine labor force efficiency.

In countries like India, individuals and groups accustomed to craft-oriented industry have had considerable difficulty in adjusting to the techniques and organization associated with modern, mechanised factories. In a highly mechanized Indian textile mill, efficiency of production and quality of output were lowered by the social values oriented to small cohesive groups. Workers felt lost operating isolated machines in a huge factory building. On automatic machines, they no longer had to service their looms, refill shuttles, or stop equipment to prevent damage, thus reducing 'craftsmen' to 'laborers'."

2.2.3 Why is the modernisation approach still popular?

In spite of many problems the modern large scale technologies have remained a popular choice until today. Several reasons may be mentioned for this persisting choice of relatively capital intensive technologies. The most important causes are the macroeconomic measures proposed by governments to stimulate industrialisation:

- Offering finance at interest rates below those in the open market stimulates investment in capital intensive industry at the expense of labour intensive industry. Equally, favourable credit facilities are not usually available for small, labour intensive firms in a form adapted to their specific needs and repayment capacity.
- Foreign exchange priced well below its real value (shadow price) encourages the importation of sophisticated equipment.
- Foreign companies are invited to settle and may be offered tax concessions.
- Wage levels may be high relative to the 'shadow price' of labour.

Besides these policies there are other factors, not directly under government control, which may also encourage private companies or individuals to invest in capital intensive technologies.

A major problem is that there are only few low-cost labour intensive technologies that are presently competitive. Research and development is required to improve the existing traditional technologies and to generate new options. The research and development efforts in developing countries are however directed principally toward capital intensive technologies. According to figures mentioned at the UN conference on Science and Technology for Development in Vienna (1979), only 4% of the world research capacity lies within the developing countries. A large proportion of this research is also done on sophisticated subjects not directly related to the development problems of these countries, while only 1% of the research in the industrialised countries is related to problems of the developing world. There is also a lack of information on the already existing small-scale labour intensive technologies.

Another factor concerning the supply of technology is that contracting agencies making feasibility studies and managing projects, do not often have an open mind to the small-scale and labour intensive option. In addition to this most manufacturers of equipment only produce sophisticated equipment for capital intensive technology.

On the organisational side there are the problems of management and human skills. The management of labour intensive production involving large numbers of labourers, demands other managerial qualities that often are difficult to come by. Lower skilled labour with low-cost technology also cannot always reproduce the quality and precision attained by a mechanical process. Local firms, however, may need this precission to compete with imported products produced with advanced equipments elsewhere.

It will be clear that to realize a change in this situation important changes in government policies and development strategies will be required.

2.3 ALTERNATIVE APPROACHES

In the seventies it was realized that the 'trickle down' did not occur and that the development of the economy on a national scale does not always lead to the desired development of local economies, particularly those of rural districts and of the peripheral zones of large towns. In addition a continuing rapid expansion of the population of most developing countries led to an increasing lack of food and employment for people in the poorer sections of the community. The development planners therefore started looking for alternative strategies to realize a rapid but balanced development.

2.3.1 Basic needs strategy

Recognition of the need for a special approach to the problem of the poor led to the formulation of the "basic needs strategy" (ILO, 1978) which stresses the importance of providing basic food commodities and low cost housing. Development, according to this strategy, should be directed towards achieving a more uniform distribution of income by generating new employment. People would then be able to buy food and basic consumption goods.

In our opinion the basic needs strategy may be seen as a modification of the modernisation approach. Although it aims to provide housing, basic consumption goods and food, the basic needs strategy does not specify in any detail what organisational structures are necessary to produce these commodities. It implicitly considers the low income and subsistence groups as consumers and as a workforce to be employed in the industries producing basic needs. Like the modernisation approach, this strategy fails to recognize that human development should match technological development, as is indeed implied in the definition of technology formulated in Section 2.1.

2.3.2 Appropriate technology

Also from the seventies onwards 'Appropriate technology' has frequently been discussed as the much needed alternative to the usual policies of technological development. Schumacher (1975), Jequier (1976) and Eckhaus (1977) explain the concept of a technology adapted to the socio-economic conditions in a country or specific location. There is however no universally accepted definition of 'appropriate technology' and various authors emphasize different aspects of the concept (see Table 1).

The words used to describe 'appropriate technology' tend to reflect the failings of large scale modern industry. Unfortunately, the term 'appropriate technology' is sometimes used to describe a piece of equipment which has some of these characteristics (low cost, simple, small scale, locally manufactures). It must be realised however, that a piece of machinery can only be appropriate in a certain place at a certain time. If conditions change, or the equipment is operated in a different environment, its characteristics may no longer be desirable. This can be illustrated by the following example.

An attempt was made to introduce biogas digesters made from oil drums into rural areas of West Java, with the aim of providing an alternative cooking fuel to firewood. Biogas digesters are frequently described as appropriate technology and have most of the above-mentioned characteristics. Indeed the value of biogas as a source of heat for cooking has been demonstrated in India and China. In West Java however, the average cattle owner

Table 1. Characteristics of 'appropriate technology'. (from Spronk, 1975)

Characteristics	Sources[a]						
	1	2	3	4	5	6	7
Labour intensive	x	-	-	-	-	x	-
Low investment	x	-	-	-	-	x	x
per employee	-	-	x	-	-	-	-
per unit product	-	-	x	x	-	-	-
per machine	-	-	x	-	-	-	-
Simplicity	x	x	x	-	-	x	-
Small-scale	-	x	-	-	-	x	-
Local oriented	-	-	-	-	-	-	x
raw materials	x	x	x	x	-	x	-
energy source	x	-	-	x	-	x	x
market	x	x	-	x	-	-	-
self reliance	-	x	-	-	-	-	-
Low risk	-	-	-	-	x	-	-
Rural preventing migration	-	x	x	-	-	-	-
Improving production	-	-	-	x	-	-	-
Independance from world economy	x	-	-	x	-	-	-

a. Sources:
1. Van Balen, 1975
2. Anon., 1977
3. Stewart, 1972
4. Onyemelukwe, 1977
5. Tuininga, 1976
6. Appr. Tech. Handbook, 1976
7. Parpia, 1974

does not have more than one or two water buffaloes, which daily provide only sufficient dung to generate enough biogas to boil one kettle of water.

Such examples of the misuse of the term 'appropriate technology' can lead to justified criticism and scepticism. Although 'appropriate technology' applies to an approach and not to a piece of equipment this is not generally realised. The people in developing countries being offered aid in 'appropriate technology' in the form of simple equipment and machinery, should therefore question the appropriateness of such an offer. It may turn out to be another example of the manipulation of developing countries by the industrialised (capitalist) societies (Dickson, 1974), but also the term appropriate technology may have become a buzz word, with little meaning and no guarantee for the quality of the offer. Such misuse is made by development organisations but also by private profit oriented organisations involved in transfer of technology (Veldhuis, 1976).

For a newly introduced technology to be appropriate in its application a liaison between those developing the equipment and its potential users must be established. Relationships must be considered not only within the target society of farmers, landless people, marginal groups and small entrepreneurs, but also between this group and more powerful sections of the community. For a succesful transfer of technology we therefore suggest, as did Goulet (1975) that:
"The leading thing for development is not to adopt the technology but rather to make a choice which is appropriate for a particular time and situation".

2.3.3 Self-reliance model

Another approach to technological development is based upon participation and self-reliance. This approach, favoured in e.g. Tanzania and China, has as a first priority the improvement of the health and education of the rural population. The people are then involved in the expansion of traditional industries. The modern sector is developed separately. This policy, known as 'walking on two legs', has resulted in the appearance of small and medium-sized industries dispersed throughout the nation, and in the growth of research and development concerned with innovations in both modern and traditional sectors. It has significant social and political advantages. Through personal commitment the participant has a feeling of serving the community as a whole while benefitting personally in some way (Rifkin, 1975).

This model is not directly applicable to other countries which, because of their political and economic structure, may not, for instance, allow full participation of the labour force or be able to protect themselves from the negative effects of the international market. Indeed, even within the Peoples Republic of China the approach was not optimal. Differences still exist between local and national economic growth and between rich and poor communities.

2.4 A TARGET GROUP ORIENTED APPROACH

The development approaches discussed so far are examples from a continuum of development strategies. They differ in the technologies considered most suitable, in the expected rate of development and in the level of analysis of the development goals.

The aspect of different possible technologies and their shortcomings has been discussed already and will receive more detailed attention in the following chapters. Closely related is the aspect of expected rate of development. This rate varies with the technology selected. Imported technologies bring a sudden change in a situation, while technologies favoured in a self-reliance approach require a more gradual assimilation of knowledge.

With difference in level of analysis we mean that the modernisation approach tends to consider development at the level of finding large scale solutions for national problems, while the appropriate technology and self-reliance approaches look primarily at the level of individual users, respectively local communities. A problem is that these differences may not be recognized because development goals are often not explicitly formulated by policy makers.

It will be clear that none of the development approaches discussed by itself will lead to a balanced development. In fact, they were specifically chosen to illustrate certain extreme tendencies, and in practice a national development strategy is likely to combine elements of two or more of these approaches. The balance in development should be found through setting of priorities and criteria, considering the overall national goals as well as the interests of specific groups. For instance, national problems such as a shortage of cereal flour may require 'national' solutions like large scale milling complexes. However such problems may sometimes be solved just as well by a multitude of small scale solutions like village service mills.

New programmes and projects should thus be planned using a consolidated approach which considers all possible solutions and their applicability for a specific target group. Such a 'target group oriented' approach can be applied to both 'traditional' and 'modern' sectors of society.

The use of a target group oriented approach in selection of technology implies absence of preferences for any specific scale or level of technology. In the following chapters however the reader may discover a certain bias in favour of low cost, improved traditional and small scale options. In sofar this is true, it is not because we reject large scale, sophisticated technologies and modern industry, but because we think that in the past the potential contributions of the small scale options have been underestimated. This is particularly the case where it concerns the possibilities to improve the food supply and the nutritional status of the rural low income population.

The serious lagging behind of the low income groups is partly the result of the modernisation approach, which created inequal development, and partly of the rapid increase in population which is not matched by an equally rapid increase in food production. In the family labour situation prevailing in these groups, the existing larger scale technologies are usually not suitable to improve the local food supply and making more efficient use of raw materials and resources. The accelerated development and introduction of labour-saving devices for agriculture, food storage and food processing at village or home level could contribute greatly towards solving these problems. The introduction of grinding mills into villages in Upper Volta, is a good example of the selection of a technology which is well suited to the needs of these target groups.

In many countries the workload of women in rural areas is very large. A workload of 15 hours per day is reported as normal for a settlement project in Upper Volta (Conti, 1970). This includes heavy tasks, such as threshing and pounding of cereals, gathering large loads of firewood and fetching water: in some villages women have to walk 16 to 32 kilometers (in the rainy season 8 to 16 km) per day. This is illustrated in Table 2, that shows an example from neighbouring Mali.

To lighten these burdens, grinding mills were introduced in a project in Upper Volta. The women actively participated in the collective decision-making about the management of the mills and

Table 2. Typical daily tasks of a woman in rural areas of Mali (from Sene, 1976).

Time	Activity
4 h 30 min	wake up, fetch water, prepare breakfast, look after children
6 h - 10 h	wash dishes, pound flour, gather vegetables
10 h - 15 h	prepare lunch, bring meal to the fields, work on the land
15 h - 18 h	gather wood, fruits and karité nuts and prepare edible oil from karité nuts (shea oil)
18 h - 20 h	fetch water, pound flour, clean house, prepare dinner
20 h - 21 h	card and spin cotton

of the resulting income. The mills allowed not only a saving of time, but also an improvement in the nutritional status of the villagers.

As McSweeney (1979) reports:
"Voltaic women tend to utilize the mechanical mill mainly when tired or pressed for time. The villagers stated however that the mill is often used to permit the preparation of meals that might otherwise be forgone. Impact of the mill is not saving time, but rather improving nutrition or increasing productivity of the labour force".

The introduction of labour-saving devices at family or village level may thus be helpful to reduce the family workload and to improve its nutrition. This however is not a general rule. The introduction of such devices to a situation of land scarcity results in an increase in unemployment (Harris, 1977). The existing situation should therefore be studied carefully and the technology should have been tried out in practice before it is introduced.

In view of such examples as this we feel that, in the long-run, a more balanced and self-generating development will be possible if smaller scale options are taken into consideration in a target group oriented programme. The following chapter explores ways of making a balanced choice from the available technologies.

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3 Consolidated approach to the selection of a processing technology

3.1 DECISION MAKING SCHEME

A logical approach to selecting a technology is to follow a decision-making scheme such as that outlined in Figure 2. This scheme is derived from general publications on decision-making, such as Kepner & Tregoe (1965). It is designed to select the best alternative and presents the steps to be taken from the analysis of the problem to the implementation of a possible solution. Each step in this scheme should be carefully considered before progressing to the next.

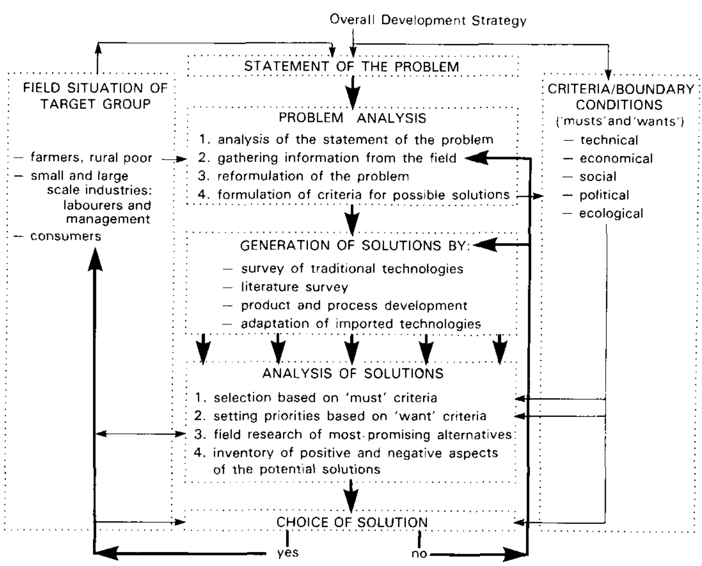

Fig. 2. Decision making scheme.

3.1.1 Statement of the problem

Initially the problem may be outlined by farmers, food processors, labourers, consumers or the government. The outline received by people in extension or research organisations should not immediately be accepted as an accurate statement of the real needs of the target group because it is likely to reflect only the interests of the person or group immediately affected by the problem. The real needs may differ from those assessed by extension workers or government officials who have not had sufficient contact with the target group to make a precise statement of the problem.

3.1.2 Problem analysis

A detailed analysis of the initial problem description usually shows that more information on the situation of the target group is required. This must be provided by a multi-disciplinary study. If, for instance, only the technological aspects of a problem are investigated, then any solution proposed may not satisfy all the socio-economic requirements. The target group should be involved at an early stage and sociologists with a knowledge of local habits may be necessary to make a comprehensive inventory of the needs of families and small industries. Problem analysis might include the following questions:

- What are the cultural wishes or constraints on a certain product or process?
- What is the existing demand for a certain product, or the market potentially available?
- How is the production and supply organised of raw-material, and what quantity should and could be processed?
- What personnel (skilled and unskilled) are available and what is their technological experience?
- How well developed is infrastructure? (raw-material transport, product distribution, water and electricity supply).
- What were the successes and failures of any other project that have been tried in the area?
- What happens if nothing is done?

The information gathered in such a study will serve two purposes. Firstly from the field information it should become clear whether the problems has to be reformulated. Secondly, with this information it is possible to define criteria for judging potential solutions. Within each problem several aspects may be envisaged. It may be necessary to list them in order of priority. The way the priorities are defined will certainly influence the type of alternatives considered at subsequent stages of the decision-making process. The quality of the information gathered during field studies will determine the success of proposed solutions. If figures on the size of the market for a product are unreliable, then there is a fair chance that the processing unit will be too large or too small.

3.1.3 Generation of solutions

Any solutions which might satisfy the needs of the target group should be considered. Solutions may either come from traditional sources, modification of existing technologies and original research or from transfer of technology from one society to another. The potential contribution of existing (traditional) technologies is often underestimated. Research is necessary for development of new technologies or the adaptation of technologies from industrialised or developing countries.

In general the research capacity of developing countries is very low. According to the U.N. Conference on Science and Technology for Development approximately 4% of the total world research capacity lies within the developing countries. The situation is often aggravated by the limited relevance of the research to the practical problems of the local population. Emigration of research workers, the brain drain, reduces the continuity and quality of development programmes. Establishment of industrial extension organisations or units attached to universities and increased financial support for research could improve the situation (Powell, 1980).

Technology transfer can take place through transfer of complete processing units (turn-key projects) or through purchase or licensing of the technology and hiring of managers or consultants (disembodied technology). The problems that may arise if technologies are introduced without sufficient adaptation have already been discussed. Adaptations are usually limited to scaling down to make the operations economically feasible and modification of the technology to suit the raw material available and meet different consumer needs (Parpia, 1974).

Private economic criteria and considerations of technical efficiency receive more attention than the social, political, economic and cultural aspects of the situation in which the technology is to function. An important additional aspect is that many technologies are monopolised by private companies which often demand high prices.

According to Ernst (1978) there are at least two reasons for companies to sell their technologies and 'know how' to developing countries:

- It extends the life cycle of technologies which are either at a high stage of maturity or will become obsolete in the near future.
- The costs of research and development are high and constantly increasing. Exportation of technology is therefore essential to recover part of these costs.

The code of conduct for the transfer of technology drawn up by the United Nations Conference on Trade and Technology (UNCTAD, 1978) attempts to regulate this trade.

3.1.4 Analysis of solutions

The proposed solutions must be assessed with reference to the criteria set by the overall development strategy and by the outcome of the problem analysis investigations. The first selection should be made using the 'must' criteria. A solution can only be feasible if it fulfils all of these criteria. The 'want' criteria are applied in a second step to select alternatives which provide the elements that are not necessary but are desirable. It is not always possible to clearly differentiate between both categories. There are technical, economic and social criteria in both 'must' and 'want' categories.

Technical criteria define, for instance, the necessary properties of raw materials, the minimum and maximum capacity of a plant, the need for skilled labour or imported equipment as well as the end-product quality. Processes differ in all of the above aspects. Socio-economic criteria include not only employment and income distribution targets, but also relationships between labourers and equipment owners. Government policy may dictate a limitation on the use of imported equipment, raw materials or foreign staff. Ecological criteria involve aspects such as the restriction of felling wood for firewood in order to prevent deforestation.

The testing of proposed solutions against a full set of criteria theoretically produces optimal solutions to problems, however their acceptability to the people concerned can only be practically evaluated in a field study. Therefore a field trial, involving both the group developing the new process and the ultimate users of it, leads to more effective development. Not only can the target group indicate potential problems, deficiencies and failures, but their involvement in decision-making will lead to a greater commitment to use the process when it is available.

3.1.5 Choice of solution

When field trials are succesful the final choice of the optimal and acceptable solution is in fact made. If none of the proposed solutions is acceptable, then a more thorough analysis of the problem may be necessary, and therefore the process of decision making should be repeated from the start. This renewed analysis should define if possible even more exactly the criteria to be used for making a choice. Generation of a wider range of solutions may also be necessary.

The sequential approach to decision-making is not new and most people follow some such scheme intuitively. The importance of thorough problem-analysis, assessment of needs and field testing of possible solutions however must be stressed. By following this decision-making scheme, agro-industrial planners and project staff should be able to make sound suggestions for the stimulation of rural development. It should however also be realized that the suitability of the selected technology ultimately depends on the exchange of information with the target group. This exchange can be viewed as a communication process. In a communication process the following elements are involved (Royen, 1972): target group, objectives, methods, message or service, and 'change agent' or organisation. The target group members are encouraged to work with the 'change agent' or organisation, and together criticise the progress of development, not only at the end but also at the beginning and middle of the project. The success of this dialogue will depend partly on the organisation and flexibility of the extension service. In the following sections we will therefore discuss the role of such an organisation and the communication process somewhat more extensively.

3.2 DEVELOPMENT ORGANISATIONS

Development projects are usually under the control of a larger organisation. This control is likely to be more effective if the organisation has clear objectives which can be used to measure the suitability or the success of a particular project. If confronted with two groups whose interests oppose, the service should refer to its stated objectives and assist the group which more closely meets these. A policy statement also enables people outwith the organisation (for example in government or international aid agencies) to assess its impact on a problem.

When tackling a problem the organisation should follow a decision-making scheme similar to that previously discussed and should encourage a close dialogue between its workers and the target group.

The success of an organisation depends on the quality and motivation of its field staff. Field workers respond to adequate facilities and the payment of allowances as well as to such less readily measured factors as good management, the possibility of promotion, responsibility and a respected status within the community.

The field of operation of a service for agro-industrial activities is indicated in Figure 3. The service could supply food processors with information on starting or improving the manu-

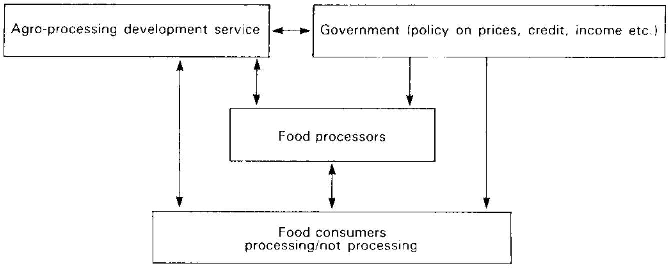

Fig. 3. Most important interrelations of an agro-processing development service and its target groups.

facture of certain food products. Alternatively it might have a responsibility to improve food processing in the household at subsistence level. These activities are directly and indirectly influenced by government policies on the price of food, income control and the availability of credit or foreign exchange.

An extension service should not only supply technological know-how, it should also provide information on the organisation of the processing activity. Some indication of the relative merits of private and co-operative ownership of machinery should be given. The pros and cons of collective management of raw material supply, processing and marketing may also be discussed with the target group. The activities of the development service are very limited if they do not include the provision of credit.

The extension service should be constantly trying to broaden its technological scope by gathering information from world-wide sources and where possible conducting its own (field) research. This activity may be performed in conjunction with a university or research institute (Youngs, 1974; Powel, 1980).

3.3 COMMUNICATION WITH THE TARGET GROUP

The decision scheme (Figure 2) indicates communication between the research or extension worker and the target group at most stages.

Often such communication is seen as a one way process. Many extension officers, especially in agriculture, disseminate their messages to farmers without listening to their experiences. It must however be a close dialogue if the transfer of information necessary for problem solving is to be effective. The development worker needs information from the target group:

- How do they define the problem?
- What solutions have already been tried?
- How do they react to the proposed solutions?
- What problems do they see in the new approach?

The target group in turn must know when they can expect a change and what economic, nutritional and social benefits it will bring.

In such a two-way communication process the parties involved alternately fulfil the roles of sender and receiver of a message or information. As the sender of a message or piece of information does not always have the same sphere of understanding or experience as the receiver, there is a danger that the message is misunderstood. To ensure against this the sender requires 'feedback'. Berlo (1962) condensed these ideas into the sender-message-receiver-channel (SMRC) communication model (Figure 4). Feedback is used to create a check on the proper encoding and decoding of intensions and meanings.

Communication between the development worker and the target group has been discussed. The target group however, is not homogeneous and there are differences in people's skills and their access to land, water, labour, inputs, markets, capital and information. These differences explain why certain technologies are adopted by some people and not by others. The extension workers should choose a target group of fairly uniform ability so that they can concentrate their efforts on the problems af-

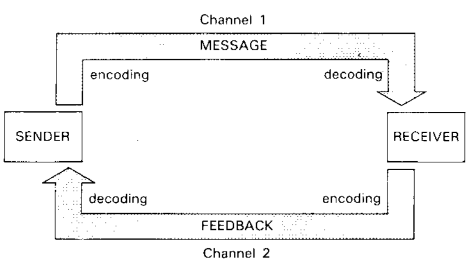

Fig. 4. Sender Message Receiver Channel - model. (from Berlo, 1962)

fecting the majority of the people (Röling, 1980).

One illustration of effective co-operation between development workers and the target population is the project on the "Appropriate Technology for Grain Storage" in Tanzania (CDTF, 1977). A team of consultants regularly held discussions with villagers about storage methods and the causes, dimensions and significance of storage losses. In a field trial in the village local structures were compared with low-cost storage methods developed in other countries such as Nigeria and Mexico. During further discussions the 'foreign' technology was criticised, modified and added to the range of possibilities already known in the village. Both sides benefitted from the dialogue. The villagers were able to reduce post-harvest losses by building new rat-proof storage structures. Their newly gained understanding of the principles of grain storage, and awareness of the technical and social variables which affect storage in their environment helped to ensure that the structures were built and used. The participating institutions were able to develop methods of 'village dialogue' which could be taught to their workers in other areas and readily adapted to different situations. They also had first-hand experience of the comparative performance of grain storage structures which would be invaluable in any future project concerned with a similar problem.

This approach termed 'action' or 'participatory' research is especially valuable for village level projects, but may also be used for small processing operations. Several interpretations of action research are possible. The elements common to all are co-operation with the target group. This co-operation serves to develop a practical understanding of the difficulties of the target group and, by transferring this knowledge, help the members solve their problems and resist undesirable changes in their living conditions (Jackson, 1979).

3.4 EVALUATION OF ALTERNATIVES

Information from several disciplines is needed to analyse a problem, gather information on alternative technologies, and evaluate potential solutions. It is neither necessary nor possible for people involved in project planning to master all the disciplines involved but they should know what information can be expected from them and what criteria for the choice of technology can be derived from this information. As was explained earlier, such criteria can be ordered in terms of musts and wants to assist in the evaluation of alternatives.

For food processing, the following fields of study are important:

- Food process engineering, food science and human nutrition, to evaluate the food technological and nutritional implications of projects.
- Economics and management to evaluate the feasibility of such projects.
- Sociology to evaluate the social aspects of improving traditional technology, introducing new technologies and changing consumption patterns; to study the need for such processes to stimulate rural development.

The contributions of these disciplines are discussed in the following chapters.

Besides these disciplines there are various ancillary topics to be considered, such as raw material supply, post harvest technology, water and energy supply, and by-products and waste utilization. These are discussed in Chapter 9 with specific reference to the problems of agroprocessing.

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4 Food process engineering

Food process engineering, the study of food manufacturing unit operations and equipment, gives an answer to the question "What is technically possible when processing a raw material?" A detailed process analysis considers the balances of mass, energy and momentum for each unit operation or for the entire process and can lead to a numerical definition of the optimum conditions for operation. On this basis any alternative process can be compared with the standard, and figures may be used to quantify the difference. This knowledge is invaluable for the development and evaluation of new techniques.

4.1 PROCESSES AND UNIT OPERATIONS

The processing of agricultural products can be classified into four broad categories (examples of each are given in Table 3):

- preservation processes which prevent spoilage or unacceptable deterioration;
- extraction of specific parts or components from the raw material;
- transformation of the raw material by, for instance, fermentation;
- manufacture of composite products from different raw materials.

The raw material undergoes successive treatments during processes. A diagram in which the successive steps are illustrated by simplified pictures of the equipment used is called a 'process diagram'. A 'flow sheet' presents the sequence of unit operations. Figures 5 and 6 are a 'process diagram' and a 'flow sheet' for palm oil production.

The processing of palm fruits is an example of a process in which a specific component of the raw material is extracted. The

Table 3. Main categories of food processing.

	Preservation	Extraction single component	Extraction edible portion	Transformation	Composite products
a. Slightly perishable crops (stable for more than 7 days) e.g.: some root crops eggs cereals pulses nuts	adequate storage egg processes (powdered albumin)	sugar milling (beet sugar) oil seeds dates (for sugar)	cashew nuts milling of grains and pulses treatment starchy tubers, roots tea processing coffee processing	bakery fermented soy products breweries/ distilleries extruded cereals gari atjeké	composite flours extruded products (e.g. pastas)
b. Moderately perishable crops (stable up to 7 days) e.g.: fruits vegetables some root crops	pickling salting smoking fermentation (e.g. kimchi) drying canning cooling (freezing)	sugar milling (cane sugar) essential oils	peeling trimming cutting de-stoning fruit juices vegetable juice	wine making jams jellies	salads
c. Highly perishable crops (stable for less than 1 day) e.g.: milk poultry sea food meats	cured meat salting drying canning cooling (freezing)	butter fish oil	slaughtering cutting fish meal	cheese yoghurt ghee dahi butter sausages	infant milk foods malted milks

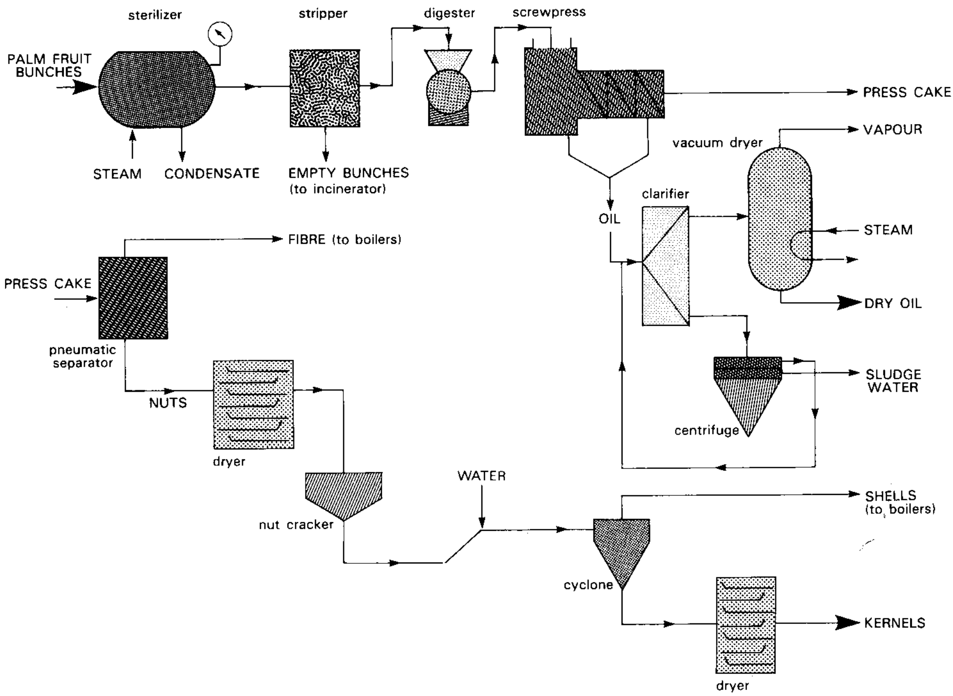

Fig. 5. Process diagram for palm oil production.

process depicted is employed in medium and large-scale operations in Malaysia, Indonesia and West Africa. Any processing step may be carried out in different ways with different equipment. The oil extraction step for example, may be achieved in hydraulic or screw presses, or by centrifugation while separation of fibre from the nuts can be done by handpicking, mechanical separation, pneumatic classification or hydraulic separation.

Flow sheets are very helpful to the process engineer because:

- they give a concise representation of a complete process;
- process variations can be rapidly compared;
- a rough idea about the complexity of the process and the equipment required can be obtained;
- heat and mass balances can be systematically developed.

Although the raw materials and products may be quite different, the operations which make up manufacturing processes are often basically the same. Evaporation, centrifugation, clarifi-

Table 4. Classification of unit operation in food processing. (from: Leniger, 1975; Geankoplis, 1978; King, 1971)

Unit operation	Explanation	Example of practical use
1. Transport		
of liquids and gases	-	pumping of water through piping
of granular materials	-	pneumatic transport of cereals
2. Size reduction	milling, cutting	cereal milling
3. Size enlargement	shaping of materials	bread making
4. Mixing	-	dough preparation, dry blending of composite flour
5. Heat transfer	heating, cooling	heat exchange in milk pasteurisation
6. Phase separation processes		
Sedimentation	-	starch recovery in small factories
Centrifugation	-	sugar crystal recovery from crystal/ molasses mixture
Filtration	-	sludge/juice separation in sugar processing
Classification	separation based on differences in density size, shape or surface properties	cleaning of cereals before milling
7. Molecular separation processes		
Dehydration	transfer of water from solid to gas	vegetable, fruit and cereal drying
Evaporation	transfer of water from liquid to gas	concentration of milk and fruit juices
Distillation	transfer from liquid to gas	alcoholic beverages
Stripping	transfer from liquid to gas	separation of aroma components from citrus juice
Ultrafiltration	separation of macromolecules from liquid by a selective membrane	protein recovery from whey
Reverse osmosis	separation of solvent by pressure difference across a semi-permeable membrane	desalination of sea water

Gas absorption	transfer from gas to liquid	absorption of amoniac from air with water
Adsorption	transfer from liquid to a solid with a large surface area	clarification of molasses with activated carbon
Ion exchange	-	desalination of whey
Extraction	may be liquid-liquid or liquid-solid	oil recovery from soybean flakes
Crystallisation	-	sugar crystal production from syrup
8. Stabilisation or Preservation processes		
Heat processing by sterilisation	-	green beans, milk and sausages
Heat processing by pasteurisation	-	green beans, milk and sausages
Cooling and freezing	-	fruits and vegetables, meat and fish
Fermentation	-	fruits and staple foods
Radiation	-	sprout inhibition, de-infestation

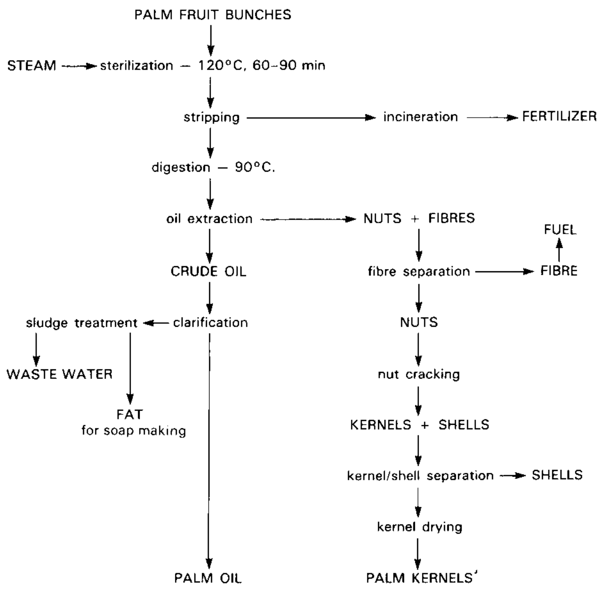

Fig. 6. Flow sheet for palm oil production.

cation and drying are examples of technique processes and are called 'unit-operations'. There are about 25 unit operations which can be divided into 8 major categories (Table 4). The classification in Table 4 is by no means complete, but shows most unit operations which occur in food processing.

4.2 CALCULATION AND OPTIMISATION OF PROCESSES AND UNIT OPERATIONS

Process calculations are based on the physical law that mass, energy and momentum are conserved. The rate of flow of material through a process and the power required to maintain production can also be estimated. From these figures the time and energy required to manufacture a certain quantity of product can be calculated. Because the efficiency of raw material and energy conversion is very important in agro-processing, such calculations are useful for comparing alternative processing methods.

Unit operations can be similarly studied by using mass, energy and momentum balances. As unit operations are not carried out in the same way for every process because of the variation in raw materials and end products, their efficiency can vary widely.

Cereal drying can be used to illustrate the range of influences which must be considered when making process calculation. Heat may be transferred by radiation, conduction or convection. Water evaporates from the surface of the cereal setting up a concentration gradient within the grain. Moisture then diffuses from the centre of the grain to its surface. Any of these transport processes may become the limiting factor for the rapid removal of moisture.

It is the role of the process engineer to supply project planners with a set of criteria for judging process alternatives. The main criteria are:

- efficiency of processes in use of raw materials, energy and water;
- capacity of each process in kilogrammes product per hour;
- labour, energy and water requirements.

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5 Food science

Food science is the study of the nutritive, chemical, microbiological and technical aspects of foods. In this chapter only chemical and microbiological aspects are directly considered, but these have an influence on the nutritive value of food and on processing methods. Food is seen by the food chemist as a mixture of chemical and biochemical substances reacting with each other, changing its chemical, physico-chemical and nutritive properties. Food science therefore is concerned with the following activities:

(1) The study of (bio)chemical and microbiological changes taking place during processing and storage of foods. For instance:

- the growth of bacteria, yeasts and molds and their beneficial and detrimental products;
- changes caused by chemical and enzymic reactions;
- physical damage, such as breaks or bruises which may lead to chemical or enzymic reactions, recrystallization, or change in moisture content;
- insect and rodent infestation;
- development of contaminants.

(2) The study of food hygiene. From the study of chemical and microbiological changes during handling of food, guidelines can be developed for the safe handling of food and quality standards may be set for individual products. The development of a national food control system is the responsibility of this field of study.

(3) The study of products and product quality. This involves not only analysis of the chemical composition of food, but also the subjective assessment of eating quality of foods by sensory evaluation. The results from taste panels may be compared with instrumental measurements of texture, flavour components and colour.

5.1 FOOD SPOILAGE AND ITS PREVENTION

Chemical and microbiological changes taking place in a food may have positive as well as negative effects. The most important criterion for the choice of processing technology is to prevent undesirable changes and to set quality standards for specific products.

Foods are perishable, but the degree of perishability differs widely for different materials (Table 3). The keepability of foods is a function of the storage temperature; increases in temperature lead to decreased storage life for all products.

The moisture content of the materials also influence degradation reactions and microbial spoilage. Moisture content is related to the water activity of foods by the moisture sorption isotherm. Water activity (a_w) (vapour pressure of water in food/ vapour pressure of pure water, at the same temperature) is the prime factor controlling the rate of chemical and enzymic degradation reactions in dry foods. The growth of micro-organisms is also controlled by water activity. The moisture content below which no growth of a given species of mould, yeasts or bacterium is possible can be determined for any product from its moisture sorption isotherm. The minimum water activity values shown in Figure 7 hold for most commonly encountered moulds, yeasts and bacteria but organisms exist which grow at water activities below the limits presented. Staphylococci, for instance, can tolerate a water activity of 0.86 and some xerophilic moulds are found to grow at a_w values appraching 0.6. Products remain subject to attack by insects and rodent pests whatever their a_w.

The adverse effects of microbial growth are most important from the public health viewpoint. Bacteria lead to putrefaction of food, and in some cases to the production of toxins. Moulds may cause discoloration, off-flavour or mycotoxin production which can be very dangerous in cereals and pulses. The prevention of microbial spoilage is thus most important and all preservation processes aim to minimise undesirable microbial changes in food. Basically one can choose between four alternatives:

- the removal of micro-organisms by filtration or centrifugation;

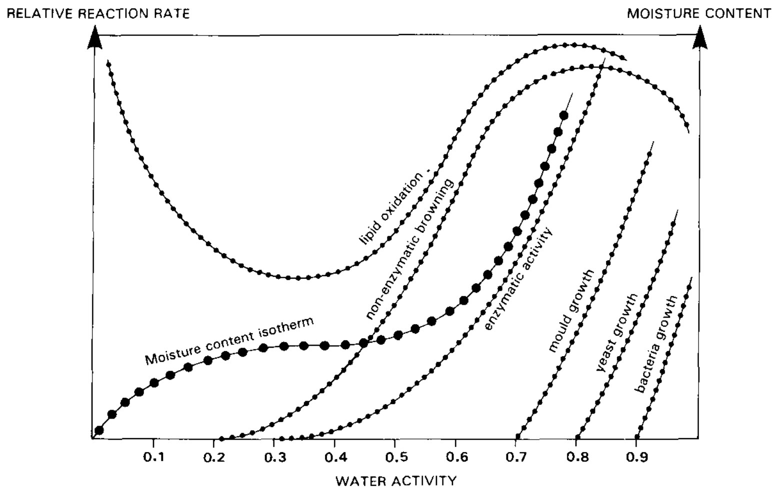

Fig. 7. Relative reaction rates of deteriorative reactions as a function of the water activity of foods. (from Labuza, 1971)

- the destruction of micro-organisms by heat or radiation;
- the suppression of microbial growth by cooling, addition of sugar, salt, acid, alcohol or preservatives or by drying;
- the encouragement of harmless micro-organisms by fermentation processes to suppress the growth of undesired micro-organisms.

Combinations of different methods can also be used.

The safety of a food depends on the number of pathogenic micro-organisms and amount of toxins per gram of product. Preservation processes such as acidification or drying which do not kill or remove all micro-organisms need special attention. Both processes have the inherent danger of including pockets of respectively higher pH and higher a_w within the product. These pockets may only exist during part of the process, but may persist long enough to stimulate the growth of micro-organisms. Because of these dangers, monitoring is necessary to ensure safety. Methods for the microbiological examination of foods are well described by Speck (1976). For rural areas and situations without full laboratory facilities the following methods may be more suitable:

- pH measurement using pH paper with an accompanying colour comparator;

- microscopic examination of gram stained samples;
- simple culture on cheap agar-covered plastic slides;
- test of water activity using paper strips impregnated with a cobalt salt (Troller, 1978). A method using common salt (Beck, 1976) is cheaper but inaccurate. Northolt & Heuvelmann (1982) describe a crystal liquefying test using several salts, each with a specific water activity.

During food handling before consumption biological and chemical contamination can occur. Sanitation of processing factories and storage centres is therefore of utmost importance to prevent food-borne infections and reduce spoilage. Sanitation problems should be technical problems but they are often managerial. Managers and labourers frequently lack awareness and interest in food hygiene. Traditional beliefs (e.g. 'beetles are part and parcel of dried fish') persist because processors are nor aware of simple measures, including better sanitation and inexpensive modification of existing equipment that can prevent infestation or reduce it to a minimum (Osuji, 1976).

5.2 FOOD QUALITY

The assessment and control of food quality is an important field of study in food science, because if consumers refuse a food for one reason or another it is worthless. Colour, flavour and texture can be measured with laboratory apparatus but sensory analysis by taste panels remains the most important tool for measuring food quality and acceptability. Food quality is not only related to eating quality as measured by taste panels scores, it is also a function of nutritional value, food patterns and food habits.

Quality control should take place at two levels. At factory level production control assures that a product is safe and of constant quality. At national level food legislation protects consumers from food adulteration, contamination and unhygienic practices. The main characteristics of the legislation are:
- a good food law;
- an enforcement system;
- an independent jurisdiction.

Although, in many countries the control of exports resides with the Ministry of Agriculture, local market control is often the responsibility of the Ministry of Public Health. To organise the development of food legislation, an interministerial body may be necessary. The work of the Codex Alimentarius Commission of FAO/WHO may be of great help to such a body (Kermode, 1975). The commission recommends international food standards and covers in its programme of work the composition, labelling, additives, contaminants, pesticide residues, hygiene, sampling and analysis of foods. The commission sends recommended Codex standards, Codex maximum limits for pesticides and recommended codes of hygienic and/or technological practice to governments. This leaves the government free to proceed in accordance with their own national and constitutional procedures. To support governments in developing an effective national food control system, FAO en WHO published a manual which can be recommended (FAO/WHO, 1976).

5.3 CRITERIA

The food science discipline provides the following criteria for choosing a technology:

- product safety;
- process conditions to obtain safe foods;
- shelf life;
- quality standards for chemical and sensory properties;
- standards on composition, labelling, use of additives, hygienic practice, sampling and permissible levels of pesticides and other contaminants.

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6 Human nutrition

Consumption is the final stage of the 'food path'. It is only at this point that the consumer critically evaluates all those factors which distinguish human food from other biological materials. Food supplies the body with energy, protein, vitamins and minerals. The nutritionist must ensure (first of all) that a diet provides these nutrients in the required amounts.

A production process may change the nutritional composition of a product and the nutritional status of people may be changed by the introduction of new products. Every possible decrease in nutrient intake needs to be viewed carefully before any change in food manufacturing is proposed. If not, it may result in a drastic increase in malnutrition among people depending on a marginal diet.

Human nutrition involves the following fields of study:

(1) Nutritional status of people, and the existence of malnutrition.

(2) Medical-physiological nutritional requirements to prevent illness. These needs are determined for different segments of the target group according to labour, age, growth and development, etc.

(3) The availability of various nutrients to the human metabolism and interaction between nutrients.

(4) Food composition and the effects of processing and preparation on the nutritional value of foods.

(5) Acceptance of foods. This involves sensory evaluation and the study of different factors which are related to the acceptability of foods:

- socio-cultural meaning of foods for segments;
- price;
- energy needed to prepare food;
- time that it takes to prepare the food;

- knowledge of its nutritional value;
- skills required for its preparation.

Human nutrition is the study of these subjects at macro-level (national or global) as well as at micro-level (individuals or groups).

6.1 WORLD FOOD AND NUTRITION PROBLEMS

At a macro-level, human nutrition studies are concerned with the evaluation of nutrition problems and with the development of strategies to solve these problems. According to FAO/WHO the main nutritional problems in the world are:
- lack of protein and/or energy;
- nutritional anaemia;
- symptoms of vitamin A deficiency, such as night-blindness and xerophthalmia;
- goitre.

Because protein/energy malnutrition is the most important of these, it is the principal subject in the following discussion.

Until the mid-seventies the world food problem was thought to be a problem of protein supply. To alleviate the so-called 'protein gap' several strategies were used:

(1) Agronomists developed computer programmes to calculate the possible rise in production of food and consequently of protein (animal and vegetable). Such research is still being carried out to evaluate several factors affecting the world food supply (Linneman et al., 1979).

(2) Plant breeders who had concentrated on developing high yielding varieties, tried to breed crops with an increased protein content (Zwartz & Hautvast, 1979).

(3) Technologists studied the production of new protein sources such as single cell protein (SCP), protein from by- and waste products, leaf protein, fish protein concentrate (FCP), and protein from legumes. These proteins can be used to enrich other products, such as bread and porridge, but are more generally used in animal feed.

(4) Nutritionists together with technologists developed 'nutritionally fortified' foods. Some of these became available on the

market as weaning foods, while others were sold as supplementary feeding for other age groups or as snacks.

The current opinion is that an inadequate energy intake rather than a lack of protein appeared to be the main global nutritional problem. Although the emphasis on protein and protein-rich foods has decreased, many food institutes throughout the world are still including the development of such foods in their research programmes.

Orr (1977) concluded that most food supplement products such as "Incaparina" and "Pronutro" often do not reach the most vulnerable groups because of their relatively high price in comparison to staple foods. If such foods are to be produced and distributed, this should be part of a national food and nutrition programme. In such programmes food fortification with vitamin A, iron and iodine, may also be useful. Preprocessed cereal/legume mixtures are however nutritious weaning foods. Although they may be produced and packed on an industrial scale, this is expensive and cooking of the legumes in simple equipment can be used to give a cheap and equally nutritious product (Worgan, 1975).

Food problems occur particularly in less favourable ecological areas and in population groups where socio-economic circumstances prevent an adequate food intake. The unemployed people in shanty towns, landless labourers and small farmers often belong to the most deprived sectors of society. Within these groups young children, pregnant and lactating women are most vulnerable. The problems may be caused by insufficient production or 'more frequently', by poor distribution. In many countries it is difficult to produce enough food for local demand while still providing crops for important export markets. More points for discussion are outlined by Lappé & Collins (1979).

At an international level many organisations are working to alleviate the world nutrition problem. FAO, WHO and UNICEF have several programmes to improve food availability for the population in general and for vulnerable groups in particular. Other agencies, such as the World Food Conference, the International Fund for Agricultural Development, the World Food Council, UNDP, UNIDO and UNEP, have programmes that aim directly or indirectly to improve the world food situation. The work of some of these organisations has been critically evaluated by George (1977).

Direct food aid programmes were mainly initiated because of existing food surpluses in the United States and Europe. Food aid is also given in situation of destitution. The Food for Peace Programme (US Public Law 480) was started in 1954 to dispose of surplus US cereal production and the European Economic Community currently sends its surplus milk powder to developing regions. The UN/FAO World Food Programme has been trying to stimulate development by linking food aid to projects, as done within the Food for Work Programme. For people involved in food production and process development it is important to know how different forms of aid affect the economy of the receiving country and therefore the local production, marketing of food and its availability to the most deprived people in society.

6.2 CRITERIA

At macro-level human nutrition can supply the following criteria for choosing a food processing technology:

- What is the effect on the availability of food commodities for the most vulnerable groups?
- What is the need for food fortification and is such fortification feasible?
- What is the effect on the distribution of foods?

Micro-level studies should assist at two steps of the technology selection process. During the phase of problem assessment, information on the following aspects could be gathered:

- nutritional status of the target group, and of different segments of this group;
- food habits;
- economic situation;
- time allocation for cooking and eating, and daily work pattern;
- common practice in food preparation;
- energy supply.

In the phase of evaluation of alternative technologies, nutrition may supply information on:

- the contribution of the product, after processing and preparation, to basic nutrient requirements;

- how the time for food preparation fits into the actual daily-task-pattern of the target group;
- comparative energy requirements for preparation of the standard and the 'improved' food;
- knowledge and skills available in the use of products or techniques;
- comparative costs of the standard and 'improved' products.

Questions such as the following should also be answered:
- how do technology and product relate to the food habits, cultural patterns and beliefs of the target group?
- if fortification of foods is proposed, is it technologically possible?
- to what extent may the introduction of a certain product or process increase malnutrition (vitamin or mineral deficiency), or decrease it?

Nutritionists should also supply criteria for food nutrition, such as those developed by the Joint FAO/WHO Expert Committees summarised in Passmore et al. (1974).

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7 Economics and management

The disciplines of economics and management can give valuable assistance in the planning and supervision of development programmes. Both disciplines can assist in the design of projects and supply criteria for the evaluation of the effect of proposed developments on private investment and the national economy. Economic standards are not the only ones for judging the success of a project and they are often overemphasised because they can be numerically quoted in terms of profit or loss. People concerned with selection of technology need not always be economists, but they should understand enough about the subject to co-operate with an economist in the preparation of evaluation studies.

To assess a problem and evaluate alternative solutions, the economic aspects of the problem should first be quantified. This is often very difficult. The economic viability of for instance, a small-scale processing operation in a 'non-wage-for-work' family system cannot be readily assessed. Such an assessment requires information about the socio-economic situation of people in rural areas. Agriculture with a long tradition of subsistence farming is the basic sector in the economy of most developing countries. Although a change towards a more market oriented society may be evident, in unstable periods there may be a shift back to subsistence farming. Subsistence farmers are often said to be reluctant to change, but one has to consider that these farmers are familiar with a balanced agricultural system that in many cases evolved over centuries to keep risks as small as possible. Their reserves if any are generally too small to risk trying to change the well-known system. People who are richer and can afford to take a certain risk, are in a better position to try new developments. Development therefore has increased inequality and in many cases the number of landless peasants is increasing.

In many regions the lack of one or more of the following factors may hamper development:

- land
- seasonal labour
- transport
- credit facilities
- technology and research directed towards the needs of the rural poor.

The development of agro-processing industries and plantations or large farms should be seen against this background of traditional agriculture.

7.1 FEASIBILITY STUDIES

When comparing the feasibility of alternative processes, studies are commonly made at different levels of accuracy. 'Project identification' is the first study which may for instance, supply general information on investment alternatives to a commercial firm or an initial selection of development projects for a national or regional government. At this stage the accuracy of the prediction is low, seldom better than 30%. This is adequate because the more promising alternatives are vetted in a further study, the prefeasibility study, before the final study on one or two of these options is performed. In the final feasibility study an accuracy of 10% may be reached. On the basis of these predictions a decision has to be made and if favourable the design phase can begin. The accuracy of the predictions is limited by the quality of information available and the time and money which can reasonably be devoted to the study. General indications of the effect on employment and the stimulation of existing industry may be more important to the policy making body than detailed calculations on capital recovery.

A re-evaluation study may be undertaken after the project is complete, to assess its impact on the problem and to compile more detailed information for future use.

7.2 EVALUATION CRITERIA

To be able to evaluate each project, calculations of the various costs factors and benefits should be made for each alternative. On the basis of such calculations money values are derived for the investment costs, annual operation costs and revenues over the lifespan of the project. Both costs and benefits to be expected in the future are calculated on the basis of their total value in the year when the project started. Such calculations are called discounting. While for the re-evaluation of an existing project such calculations can be based on data derived from book keeping, the evaluation of future projects may require data to be estimated from available statistics on comparable operations. Cross-checking is necessary to increase the reliability of these data.

Two criteria are commonly used in project evaluation:
(1) The Nett Present Value (NPV) which is the value of discounted benefits minus discounted costs (B-C) shows the profit from a project.
(2) The Internal Rate of Return (IRR) which shows the rate of return that capital makes when invested in a project. It shows the profitability of a project and can be compared with the rate of return on capital otherwise invested in that country.

To calculate B-C or IRR, one must know the cost of inputs and the price of outputs. These may be different in calculations made from private and national pounts of view. Private enterpreneurs should for instance calculate on the basis of the costs charged to them even if the government is subsiding certain products or services. They must also include taxes in their calculation. When a national economic analysis is made, prices without subsidies and taxes should be used. The 'shadow price' should be used, which represent the contribution that each production factor would have to the national economy if the project was not carried out.

Both criteria can normally be used. However, when project alternatives exclude each other (which means that only one of them can be carried out), the correct criterion is then to maximise B-C for the first limiting factor. These criteria only evaluate the profit rate of the factor capital. This may be beneficial in the case of a private economic analysis for one company, enterpreneur, or cooperative which wants to see the profitability of a certain investment, but at national level policy makers often need more information that can only be provided by a more comprehensive feasibility study. This should consider various aspects including:

- How does a project relate to the national development goals?
- What are the direct and indirect costs and benefits of a project?
- How do changes in external factors effect the outcome of the project?

Numerical valves can be placed on these factors if sensitivity analysis is performed. If for instance the raw material supply is uncertain, the profitability of alternative factories should be calculated when operating at 100%, 80% and 60% of their capacity. When selecting a project option that is designed to create new employment, it is necessary to know how changes in the cost of labour and capital affect its viability. Projects that are more labour intensive should show a higher profitability (IRR) if labour costs are decreased or the interest rate is increased. The internal rate of return in such calculations is then called social rate of return. The government is in a position to create employment directly in the public sector, and indirectly in the private sector by increasing interest rates and thus encouraging enterpreneurs to adopt labour intensive technologies. In a similar way, those projects that make by-products and wastes available for re-utilisation can be favoured. Extra costs are, in that case, attributed to useless by-products in cost-benefit calculations. It is however difficult to determine the weight that should be given to various factors in these calculations, because of the problems in giving numerical values to certain social benefits and costs.

With these techniques the range of project alternatives can be evaluated. The following two examples may explain what kind of alternatives may be compared and how.

Example 1 - Production of vegetable oil

Many countries that export unprocessed oil-seeds must import the refined edible oil to satisfy local demand. The development of local oil extraction capacity would provide a stable market for locally produced oil-seeds, create employment and reduce demands on the country's foreign currency reserves.

Different technologies are available for processing oil-seeds. These range from large-scale solvent extraction, through medium-scale expelling to small-scale pressing with hydraulic presses. The extent to which the crude oil has to be refined depends the type and quality of oil-seed, the extraction system selected, required storage life and the consumers quality expectations.

In an evaluation study the following aspects need to be examined to compare the different technologies:

- scale of operation in relation to raw material supply and transport;
- need for management-, operation- and maintenance skills;
- market size;
- product quality required;
- employment generated by the process;
- need for imported equipment.

This list is not complete as it gives only those factors which are independent of the country or region in which the project is located.

Example 2 - Drying of maize after harvest

In the humid tropics of West Africa, maize may be harvested when fully ripe, but at that point it still contains too much water (approx. 24% (w/w)) for safe storage. Traditionally, farmers leave the crop unharvested to dry in the fields until a safe moisture content (approx. 14%) is reached. By then insect and rat attack may have caused considerable losses, especially of hybrid varieties. Harvesting the maize when ripe, and drying the crop immediately, can reduce these losses.

On a small-scale this could be done in two ways:

(1) Storage on the farm in well ventilated cribs. Using this method the cobs dry within a few weeks, the exact drying time being dependent on the crib design and ambient conditions. The requirements for the introduction of new cribs in terms of materials and financial credits are modest. Running costs are for the regular spraying of the cribs with insecticide and for their repair and eventual replacement.

(2) Shelling following by air drying in batches in simple heated crop driers. These would be located in villages and could be either privately or co-operatively managed. In this case the drier chosen must suit the quality and quantity of maize to be dried, the amount of moisture to be removed, the type of fuel available and the social structure of the area. Calculation of the running costs requires estimates of the drier capacity necessary to dry all the 'wet' maize within a safe period, fuel, maintenance and replacement charges. The availability and cost of credit should also be investigated before any estimate of the return on investment can be made.

The evaluation study should compare the economics of proposed solutions and traditional methods which would be used if the project was not carried out. The costs of the proposed new processes must include the costs of development or extension services where relevant. The economic benefit of the project is more difficult to assess. Some value must be placed on the maize saved by the new storage methods that would have been lost by traditional ones.

7.3 PROGRAMME AND PROJECT ORGANISATION

Projects should always be part of larger development programmes. In programme design the viability of the total programme as well as of each separate project needs to be tested. To facilitate the smooth running of a programme or project, the management should find answers to a number of questions at the design phase as these answers may be of outstanding importance to its viability. Some of the following questions have been adapted from Aylward (1967) and ErSelcuk (1970):

Inputs

- Are there alternatives to the programme? If for instance government involvement is considered, why is the activity not be left to, or taken up by private enterpreneurs? What happens if nothing at all is done?
- How will the raw material supply be ensured? Is it possible to get a constant supply of water, power, transport, auxiliary chemicals and packaging material? Is the necessary amount of labour with the right skills available?
- Equipment and buildings are a crucial factor in many projects. To what extent is it necessary to set up completely new systems? Will it be necessary to import capital goods or can they be produced locally? If imports are required, will the necessary amount of foreign currency be available on time? Importation of equipment may also involve technical consultants and maintenance technicians from abroad. Is it admissable that there is such a high degree of dependency?

Organisation

- Is it necessary to educate managers specially for this project?
- What role does the balance of different political groups, tribes, regions, sex, etc. play in choosing personnel for a programme? What is likely to be the influence of middlemen?

Outputs

- Are markets available for the products? Has the size of these markets been overestimated?
- Has effluent disposal and waste and by-product production been forgotten?

General

- How does the location of the factory relate to its inputs, organisation and outputs?
- Is it clear from the study what is included in the project and what not? Is the organisation of inputs and outputs to be part of the project?
- What is the quality of the figures presented?
- What risks and spin-offs can be envisaged?

These questions are particularly useful when assessing the report of an evaluation study. There are also indirect questions that have to be considered. Asking "From where does the project proposal originate? Who will support it and who will be against it?" may help to discover the socio-political validity of a project, and why certain solutions and technologies have been suggested.

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8 Social sciences

Only a few years ago it was common practice to ask for the advice of sociologists when the approach to a project had proved to be unsuccessful. It is now realised that adequate field work with the assistance of sociologists is necessary before beginning the project, during its development and after the project has finished.

Before any examples are given, it may be wise to show how the sociologist's approach differs from the technologist's. Technologists generally look firstly at the technological advantages and disadvantages of processing methods. A sociologist is primarily interested in understanding why people behave as they do. He or she tries to see issues as part of the social situation of the people. A technologist in many cases, is inclined to isolate parts of a process and make a profound study of one or more of these parts.

The sociologist stresses the need for an analysis of the existing socio-cultural and economic situation, because each new technology has to compete with already existing practices, and to fit in with existing socio-cultural values. A sociologist can evaluate how different technologies help the community or specific target groups within it to reach higher levels of prosperity. There are two main fields of social science study which are important when choosing a technology for rural development. The first is the influence of technological development on the household situation and the criteria from the household for the choice of technology. The second is the relation between technological changes and activities at community level.

8.1 THE HOUSEHOLD SITUATION

Agro-processing activities in rural areas cannot be seen apart from "the social institution of the household" (Edema, 1979). The women's work load in many rural areas is very heavy and involves agricultural production as well as processing and marketing activities (FAO, 1979). Any change in the way of production or processing may mean a drastic change in time allocation within the family. It will be necessary to evaluate the effects on the household of any proposed change in processing activities. This may be illustrated by a few examples.

Starting a sugar factory may increase the market for sugar cane and stimulate farmers to grow more of it as a cash crop. They will need more time for cultivation of the cash crop and have less time and land available for food crops. This may affect the food supply to the family.

A new processing factory may also influence the income of rural families, if a competitive product is produced. A good example of a study that analyses the existing food processing activities is that of Simmons (1975) on small-scale rural food processing industry in Northern Nigeria. In this study she analyses the social and economic value of existing processing activities. She also analyses the influence of competition from a large-scale modern industrial plant producing similar products; in this case groundnut oil and milk from similar local raw materials. When the study was made, no real competition existed due to high investment costs and raw material transport costs that kept prices of industrially manufactured products above those of the small-scale producers. However, this may change in the future because of an increasing rural demand for "modern" products, and because the factory takes over the burden of production from the rural families.

Starting a processing activity may also have positive effects, as in the case of cereal milling mentioned by Lewis (1965) and O'Kelly (1973). When time is a limiting factor, a village mill for cereals may give women more time to attend to the production of food crops. It can have a negative effect in situations where employment is scarce and people earn an income by processing cereals for other families. In Bangladesh; "each mill displaces about 300 women" (Ahmad & Jenkins, 1980).

8.2 COMMUNITY ACTION

Depending on their scale of operation, collective processing may be attractive for some production techniques. Cereal milling by hammer mill or palm oil production with a hydraulic press requires larger investments than individual small farmers can make. A group of small farmers however may be able to afford this financial outlay and can then take advantage of the increased capacity such equipment provides.

If any equal distribution of income is intended, processing as a co-operative may be a more attractive proposition than having one private enterpreneur who collects the revenue from the processing operation. Co-operative action is however not always an appropriate solution. Its success depends very much on the history and socio-economic structure of the community, and on a proper analysis of all the functions of its central unit. In the case of paddy husking in Bangladesh (Ahmad & Jenkins, 1980) milling in Cameroun (O'Kelly, 1973) a co-operatively owned and managed mill is the only option which prevents women from becoming unemployed by the activities of a private enterpreneur. It is clear that a community needs to be studied before any change in processing activities is introduced.

8.3 CASE STUDIES

To give more background to the remarks made above, and to explain the need for a sociological opinion on agro-processing projects, some case studies are presented. From these examples we draw conclusions at the end of this chapter about the task of a sociologist.

8.3.1 Palm oil press

Traditionally, the production of palm oil in oil palm and cocoa growing areas in Nigeria is quite a labour intensive process and results in a low rate of extraction. Oil processing however reaches its peak during the off-season for cocoa production and is therefore a subsidiary occupation of the people in this area. The men harvest the fruit, and the women crack the kernels and process the oil.

For generations the extraction of oil from the oil palm fruit has been a chore reserved for the women of a village. It engages a large number of them and takes several hours to complete. The process is slow and requires the expenditure of considerable time and energy. The process starts with boiling the fruit in a drum. After boiling it is pounded into a pulp in a mortar (a dug-out tree trunk placed in the ground in a longitudinal position) with heavy wooden pestles. The pulp is put into the processing pit, a fair-sized hole in the ground lined with cement or plaster. Cold water is added and stirred with the pulp. The nuts separate from the fibre and sink to the bottom. The fibre settles on top of the nuts and the oil floats. The oil is then skimmed off and boiled to get rid of any water in it. The fibre is removed from the pit, deposited in a bag, and squeezed to wring out any remaining oil. A sediment remains in the pit after draining off the remaining water. The processing pit has three by-products that are the women's reward for their labour: palm kernels, fibre and sediment. The kernels are generally sold for processing elsewhere, while the fibre and sediment are dried and used or sold as fuel.

The oil yield of this traditional process is only 40-50% of the oil available in the fruit. Pressing the hot pulp in two stages with a hydraulic press may increase the yield to 90% (Nwanze, 1965). The potential increase in oil yield and the necessity of diversifying agricultural production in an area prompted the Ministry of Agriculture in Nigeria to introduce the hydraulic press to a village called Gbebun.

During meetings with the villagers only a few women were there to discuss the new press. They were assured that the introduction would not deprive them of their usual share of the palm kernels. It was found that of the women involved in oil production before the introduction of the hydraulic press, 16% never used the press and 60% stopped using it after some time.

The following reasons emerged for not using the press:

- Because of the increased rate of extraction, by-products contained less oil and therefore their fuel quality was lower.
- The hydraulic press operated by government staff was only available from 7 a.m. to 3 p.m. The hours of work at the processing pit were not so scheduled; the women only stopped when the job on hand was completed or when darkness fell.
- The mortar for crushing seeds was developed for men, while traditionally this was a woman's job.
- During the peak season the capacity of the installation was too small.
- The oil produced belonged to the men. Women did not sustain their interest.

We may learn a few things from this case that was described by Obibuaku (1967). Although meetings were held and ideas exchanged, the villagers did not get enough time to think about what the proposed improved technology would mean to them. The role of the women in family decision-making was underestimated and they were not sufficiently involved in choosing the technology and introducing it. The villagers did not participate financially in the installation of the press and it was not operated by them. It remained too much a government project.

8.3.2 Corn mill societies

In the fifties an attempt to reduce the workload of women in the Camerouns, was based on an analysis of their working methods. An obvious hardship was the work involved in grinding maize into flour. This they did between two stones, a large flat one on which the corn was scattered and a smaller stone, held in the hand which was rubbed backwards and forwards over the surface of the larger stone. It could take an hour or more of monotonous work to produce even a small quantity of flour and the women's hands were often covered with callouses.

It was suggested that hand-operated corn mills might solve this problem. With an output of 16-18 kg an hour and operated by two women (manufacturers data) such mills could be a considerable improvement. In one village the women reluctantly agreed to a demonstration; they were afraid of the unknown. Initially the maize was not dry enough and women who had been turning the handles had not yet caught the necessary rhythm. In a few days time, however, the situation had changed, people became more familiar with the machine and it was soon in constant use.

The costs of a mill were too high for most individuals but not beyond the reaches of the women collectively, so a corn mill society was established. Soon there were requests from other villages to set up corn mill societies. There were on average 70 members to a society. They were able to raise the money and thirty villages repaid the machine within a year. Each society chose two head women who held the key of the hut in which the mills were kept and even though they were illiterate, they knew very well who had paid and who had not.

As the societies became established and the women had more leisure, the women's thoughts began to turn to other matters. They met frequently while waiting their turn to use the mill, and raised ideas to have classes in such subjects as soap making and cookery. They built community halls to be able to have classes also during the rainy season. Gradually the range of subjects was extended to include child welfare and hygiene. This improved the nutritional situation of children. Other collective activities were undertaken, such as the improvement of the water supply and establishment of a shop run on co-operative principles.

We may see from this example (O'Kelly, 1973) how the introduction of a labour-saving device not only succeeded in reducing the workload of women, but also how they learned to organise themselves and start other co-operative activities to improve their lives.

The demonstration organised with the women was very important, but the claims of a native doctor, that the survival of a sick old lady was due to the use of maize flour produced by the new machine, also encouraged use of the mills. It is not clear how, in this case, the women succeeded in overcoming the problem of the different taste of the flour. It is often reported that milling between stones in the traditional way gives a better taste to the cooked product. This might be a reason why machine milling with metal plates is sometimes not adopted.

From this example it seems to be clear that hand-operated grinding mills considerably reduce the time required for the production of maize flour. In Tanzania, however, this was found not to be the case (CCT, 1980). Of the machines tested, the 'Atlas No. 3' mill gave the best results. It proved capable of satisfactory grinding softer smaller grains but needed adjustments to enable it to grind maize at a speed and in a manner which the villagers found acceptable. Grinding in 3 or 4 stages with sieving between them was necessary to produce a suitable flour. This corresponds very closely to the traditional procedure, the only difference being that pounding is replaced by hand-grinding. Most people considered the benefit of this change to be small or non-existent and either walked to the nearest engine driven hammer mill or continued to use the traditional method.

From the available information it is not clear what the most important differences between this example and that of the Cameroun corn mill societies were. It could be that the target group knew of the existence of hammer mills in Tanzania in 1980 and although the equipment was not available to them, they were reluctant to use any piece of new machinery which was not self powered. Perhaps people in Cameroun in the 1950's had no knowledge of hammer mills and readily accepted a more efficient hand milling technique.

That social issues can control the choice of milling technology is clear from the Tanzanian evaluation study in which a bicycle-operated grain mill, developed by the Tropical Products Institute (Pinson, 1978), was examined. This machine was unacceptable, partly because it was traditionally men who rode bicycles and the village women found it embarrassing to do so. The mill was incompatible with the roles of the sexes and the division of labour in villages. Moreover, although this mill was able to produce reasonably good flour, the output was very low: only a kilo of maize flour every 2 to 4 hours.

8.3.3 Tomato processing

The case study described by Agbonifo & Cohen (1976) discusses the excess capacity of a vegetable processing plant in Northern Nigeria. "To operate efficiently the factory must process somewhere near its capacity of 60 tons per day. However, it received only enough supplies to process eight tons a day". The excess capacity was due to a lack of understanding of the local socio-economic order and not to technical unsuitability of the processing plant.

Dry season tomato farming was introduced to villages in the area of Zaria. Participants in the project were obliged to sell their crop to the company for the manufacture of tomato purée. Farmers had to pay for agricultural services, such as the supply of fertilizers and seedlings and therefore received prices lower than those in the open market. Many producers therefore sold their tomatoes on the open market. The project did however increase farm incomes. The percentage of production that was delivered to the monopoly company varied. Leadership and the attitudes to leaderships that existed in villages turned out to be significantly associated with the amount delivered. If there had been no established relations between peasants and the authorities before the project, these authorities were mistrusted. When leaders were elected by the people themselves, they were trusted and their organisation co-operated by delivering more tomatoes to the industry. It was recommended that the government should subsidise services to the project to prevent unfavourable competition with the open market, and that farmers should be allowed to create their own organisation for managing services and marketing of crops.

The following problems played an important role in this project:

(1) Services should have been supplied by the State Ministry of Agriculture but financed by the company. The company had provided transport facilities, fertilizers and seedlings, as well as partly supplying tractors and irrigation equipment. In return it paid a low price for the crop and deducted 30% for its agriculture services.

(2) The efficiency of services was low. Tomato yields were seriously affected by a delay of two days between transplantation and watering. Over 80% of the farmers reported delays longer than two days which resulted in 63% of them having to purchase fertilizers, water and fuel for the pumps with their own funds. On a number of occasions the trucks for transporting the harvest were not available as promised. The fact that extension workers were not paid on time is only one of the reasons for the inefficiency of the services.

(3) Research findings indicated that there was general resentment at being organised by the traditional political system and therefore, against the leadership of the political head of the village. It was alleged that many political heads were selfish in the use of the water pump. Tomato plants, fertilizer and water were not equally shared but those holding political or religious offices were given preferential treatment. Some chiefs were alleged to demand money for inputs supplied by the development workers. Others were said to be selling fuel supplied for the project to corn grinders in the villages. Farmers usually sold tomatoes to traders to recover the extra costs. The hypothesis that the non-acceptability of the group leader is related to the unsuccessful adoption of the project was consequently accepted.

8.3.4 Water supply

During 1968 the Brace Research Institute of McGill University of Quebec, Canada, became involved in a water supply project on the island of La Gonave, Haiti. The project was evaluated by Lawand (1979) who analysed the factors affecting the success of the solar distillation plant contructed:

'An extended period of drought during 1967 and 1968 showed that the rainwater catchment and storage system was not an adequate long-term solution to the fresh water problem of Source Philippe, a small fishing and farming community. The reforestation programme which had been started would not significantly improve ground water retention for one or possibly two generations. Drilling for fresh water in the surrounding hills had been tried but without success. One possible solution proposed by the local leadership was to find a way to extract fresh water from sea water, or from the brackish and polluted well water. A solar distillation system was selected because it met the specific needs of the community. Most of the construction materials and all the skills for construction, operation and maintenance were locally available and there would be no need to import fuel to operate the plant.

Construction of the installation was labour intensive and most members of the community, including men, women, and children, were involved at one time or another. The only items imported into the village were the glass, the rubber basin liner, and the sealing compound to hold the glass in place....

....Briefly, a windmill is used to pump brackish water from a well up to a slightly elevated water storage tank. The brackish water then flows by gravity into the solar still basin, where the water is heated by the sun's radiation. As the brackish water is heated pure water evaporates and condenses on the underside of the glass, which is cooler than the air inside the still. The condensed water flows down the under face of the sloping glass into a gutter. The pure water then flows by gravity through the gutter and into a fresh water storage tank. The solar still operates best when the sun is shining but it does function at lower output under overcast conditions. Soon after it was completed the solar still was producing an average of 1250 litres of fresh water per day from brackish and sea water.'

A sociological study was undertaken eighteen months after the solar still was completed. From this study it may be concluded that the plant did not adversely affect the traditional social patterns of the village. The stills replaced the well as the focal point for water collection, and the usual social activities associated with this operation. The technology may be called 'appropriate'. If it had not been so, the systems would have long since fallen into disrepair and disuse due to technical difficulties. It is remarkable that the plant has been in continuous operation during the period of study. Up to 1979 only very rarely was a piece of glass broken. The population participated fully not only in the selection and building of the solar stills but also in their operation and maintenance. They were concerned about the health of the child and adult population and felt the need for clean water.

Another important reason for the success of this project may be that the Methodist Church had an influence not only on the local structure and village council at the site of the still, but also in the capital city of Port au Prince. The Methodist Church under the leadership of a Haitian agronomist, who was familiar with the village and the island of La Gonave, supported the project. Often however, when new technologies are introduced, the motivating forces which could ensure the continuity of a project do not receive enough attention.

CONCLUSIONS

On the basis of the above examples we contend that sociologists can help in choosing a food processing technology. Sociological questions can arise at each stage of the decision-making process.

(1) Problem analysis phase

- What are the actual problems of the target group? This includes target group selection and ensuring that the target group is involved in the assessment of its needs. From the 'palm oil case' we can see that low oil recovery was not the problem of the processors. That would certainly have become clear if an assessment study had been undertaken.
- What is the history of technological change among the groups concerned? The experience of the target group with previously tried alternatives should indicate what skills are available in the community, and what innovations will be possible.
- Which socio-economic conditions have to be taken into account? Male-female labour distribution patterns were not studied in the first case, consequently the role of women was underestimated. In the last case the social function of a pond as meeting point was realised.

(2) Phase of analysing alternative technologies

- What are the basic assumptions behind each alternative? The alternatives proposed should comply with the perceived needs of the target group.
- How can feed-back from the users be obtained? Field testing should be organised in such a way that the target group is able to assess various alternatives. In the example on palm oil processing, the time given to the villagers to think about the value of the proposed technology was too short.
- What are the prevalent attitudes to the proposed change? This can only be found out when the target group is involved in the evaluation of alternatives, as happened in the 'water supply case'. In the 'palm oil case' the involvement was inadequate.
- What is the danger that an alternative processing method could increase the socio-economic differences in society? Who will profit from the new or improved technology and who will possibly have a disadvantage? These are questions to be answered. Such questions are related to the organisation of a project as illustrated by the 'tomato processing case', in which there was a general resentment at being organised under the traditional political system.
- How are risks perceived?

(3) Technology introduction phase

- What effects are not intended? The lower value of the by-products was an unintentional negative effect in the 'palm oil case'. Women's organisation was a positive effect in the 'corn mill case' which was not initially envisaged.
- What feed-back is available? Feed-back is required to receive reactions on the use of the new technology and to determine the need for further development work. A programme to gather this information should be devised before completion of the project.

(4) Re-evaluation phase

- How can the results be generalised for other innovations?

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9 Specific aspects of agro-based industries

Agro-based industries are concerned with processing raw materials of plant and animal origin. Food processing in particular aims at the production of food for human consumption. Processing however is only one step in the whole system from harvesting to consumption. This system is illustrated in Figure 8 by the so-called 'Food Path'. An important aspect to consider is that all stages are linked with each other. Each of the processing steps should only be studied in relation to those before and after it in the 'food-path'. When comparing different alternatives for one of the processing stages, their effects on the whole system should be evaluated.

In this chapter some important aspects of agro-processing are discussed. Some are stages in the 'food path' itself, such as raw material supply, post-harvest loss reduction and storage. Others, such as water and energy supply, and the utilisation of

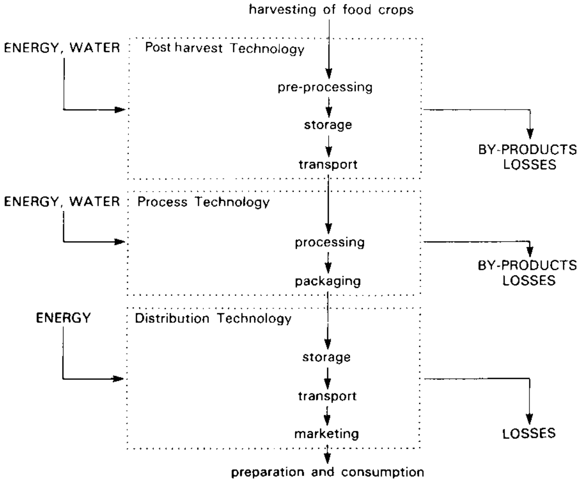

Fig. 8. The 'food-path' from harvesting to consumption.

waste and by-products are not. They are however essential adjuncts to any food processing operation. No specific attention is given to pre-processing, transport and marketing. This does not mean that these aspects are of less importance. Drying for instance is important in the pre-processing of food grains and will be partly discussed (Section 9.2) in view of its importance as a method of preventing losses. Another important aspect, especially for small-scale industries is marketing. There is a growing need for information on this subject to ensure that products from such industries can be marketed locally and eventually internationally. Although the FAO has published a bulletin on small-scale marketing of fruits and vegetables (Abbott, 1978), general information is scarce.

9.1 RAW MATERIAL PRODUCTION

A good supply of raw materials is essential for any processing operation. As we have seen in Section 2.4, the lack of raw materials is often a cause of the under-utilisation of existing processing facilities. Either the quantity or the quality of the raw materials may be inadequate. In general a raw material for an agro-based industry should have the following properties:

- either readily available with no seasonal fluctuations or seasonal available in predictable quantities;
- uniform in quality;
- stable during storage;
- stable in price.

The more capital invested in processing equipment, the more important these properties become. When exceptional surpluses need to be processed to prevent spoilage, these requirements may not be satisfied and this will certainly affect the quality of the end-product.

The need for a more uniform supply of seasonal commodities throughout the year and the importance of additional income for small rural communities may nevertheless be a stimulus for technologists to improve small-scale processing units for these crops.

9.1.1 Raw materials of plant origin

Development planners should not only encourage farmers to grow a certain crop, but also collect information about the best way to stimulate rural development. 'Should a family grow its own food or should it grow a cash crop instead?' and 'How can farmers be encouraged to increase their agricultural production beyond their family's food need?' are questions that need to be answered.

High yielding crop varieties can potentially increase agricultural output and food production at a national level. For small farmers however, these varieties are sometimes not interesting because of the need for more inputs. High yielding cereals may be more susceptible to pest attack during storage and the short cycle grains can be difficult to dry. The new varieties increase risks for the small farmers. In this way measures to increase production can have a negative effect on rural development.

In many cases food industries process seasonal commodities. Perishable materials such as fruit and vegetables should be of the right quality and should arrive at the factory gate in time. The organisation of raw material supply therefore deserves special attention. If it is not socially and economically acceptable to the farmers the supply will breakdown as we have seen in the case of tomato processing (Section 8.3.3).

In order to employ labour and utilise the capital equipment all year round, various products may be processed throughout the year. The establishment of a so-called multi-purpose plant appears to be attractive (Hurler, 1976; McGreavy et al., 1979), experience however has shown that it is difficult to make such operations profitable. The economies of a large scale operation cannot be obtained and good scheduling of factory operations is necessary to ensure a succession of products. Stable commodities such as grains and oil-seeds which can be stored between harvests do not present this problem (Aylward, 1967).

The quality of raw materials for the food industries is a special aspect, as materials may be suitable for the 'fresh' market but not for processing. In the case of tomatoes, it is well known that both purposes require different varieties. This means that surpluses may not easily be processed to prevent them from spoiling. Produce left over from the fresh market should not be considered suitable for preservation. A food preserved by canning or drying, cannot be of better quality than the original raw material.

9.1.2 Raw materials of animal origin

Meat, fish, milk and eggs contain large amounts of high quality protein and contribute energy as fat and B vitamins to the human diet. Animal proteins however are not essential for humans if the diet provides plant proteins in sufficient quantity and quality. Animal products, apart from milk, are usefull sources of iron. Iron is less readily absorbed from plant materials than from animal sources. The amount of meat produced per kilogram of animal feed, in other words the feed conversion factor, varies for different species and breeds. In many cases however animals are mainly fed with materials that cannot be used for human consumption. In such cases they form a valuable and important source of additional food. If animals are fed on plant materials which can be eaten by man, this in fact reduces the total amount of food available to humans.

Game, and wild animals bred on farms are an important commodity for industry and the fresh market. In many countries more than 50% of the meat consumed comes from this source. Fish from rivers, lakes and seas is a raw material which is produced without any input of capital. Large modern fishing vessels are very effective at catching fish because of their large nets and sophisticated fish finding equipment. However, catching the fish by these methods employed in industrial countries is very energy intensive. An industry processing fish that is caught by these techniques, can only be economical if wastage is low and fish prices high. If this is not the case, it is worthwhile considering the less energy intensive options (which are also more labour intensive) of catching fish with hooks and lines or investing in fish farming projects.

Meat and fish are processed to prevent spoilage and to separate the by-products. Preservation by canning or freezing has the disadvantage of requiring much energy, equipment and packaging material, making the product relatively expensive. Cheaper methods such as sun-drying, fermentation, salting and curing are recommended, but they may need to be adapted to suit the taste and food habits of the target community. (Curing is a modification of the salting process in which additives are used to improve the colour and flavour of the product.)

Milk supply to dairies of the type currently used in industrial countries requires good organisation and sophisticated equipment.

- Milk is highly perishable. In a hot climate it should be processed not more than 4 hours after milking unless chilled.
- Chilling is expensive because of the high equipment and energy costs.
- Dairies need a permanent energy and water supply.
- As milk often has to be collected from groups of farms a considerable distance from the processing plant, a reliable transport system for collecting it is essential. Pasteurized milk also requires a reliable distribution system.
- Highly skilled labour is necessary.

Small decentralised milk processing plants can be a good alternative. Farmers in the immediate vicinity of the plant can bring their milk to it within 4 hours (Bachmann, 1981). For more distant groups of farmers, chilled collection centres or the use of H_2O_2 for preservation have been suggested. Energy supply to the dairies in the form of solar energy, bio-gas and hydroelectric power could be possible. The manufacture of products that do not require permanent chilling for transport and retailing is to be preferred (fermented products, ghee, butter). Heat treatment of the milk is essential in areas where diary herds are not free from tuberculosis and brucellosis.

9.2 POST-HARVEST TECHNOLOGY

Harvesting is the action of separating the foodstuff (with or without associated non-edible material) from its growth medium; replacing cereal, picking fruit or lifting fish out of the water. Succeeding actions are often defined as post-harvest actions (NAS, 1978). In the context of this book however, this definition is too broad and post-harvest technology is only used for the sequence of operations between harvesting and processing.

Post harvest handling, processing and distribution aim to supply products, which are marketable and which fulfil the demands with the least possible losses. As indicated in Figure 8 losses may occur during every stage of the 'food-path'. While by-products may have some value for other uses, waste, spillage, pest attack and contamination cause real losses and thus decrease the amount of food available for consumption. It is important to realise that damage and loss does not mean the same although both may result in the loss of weight, quality, or nutritive value. Each of these criteria may have economic implications, which can be different for the individual farmer and for the nation as a whole.

In programmes aimed at improving the post-harvest system, it should be realised that interest in developments that decrease food losses is influenced by various factors, such as (N.A.S., 1978):

- price depression resulting from increased availability of food;
- taxation;
- inadequate means of storing and marketing surplus production;
- obstacles to reaching larger markets, such as the lack of feeder roads or transport facilities;
- requirement for improved storage structures;
- extra time necessary for processing the increased quantity of raw materials;
- consumer preferences;
- tradition.

Technologists involved in post-harvest loss reduction programmes should rely not only on technical but also on socio-economic information. Many production and post-harvest systems on small farms are linked with tradition, security and status. In many cases it is the woman's and not the man's responsibility to process and store food crops.

9.2.1 Losses

Storage is only part of the post-harvest system in which losses may occur. Rice loss estimates (in %) for the Philippines are reported as follows (de Padua, 1974):

Harvesting	1-3
Handling	2-7
Threshing	2-6
Drying	1-5
Storage	2-6
Milling	2-10
Total range of losses	10-37 % (of initial weight)

For most countries and products specific figures are not available but global estimates demonstrate that post-harvest losses are considerable. For cereals and legumes, losses varying from 0 to 70% have been reported (FAO, 1977a) and for perishable crops the estimates range from 10 to over 50% (FAO, 1977b). The FAO reports that in some countries the losses of fish may be amongst the highest for all commodities. The very high figures sometimes mentioned are certainly exceptions and may include the amount of produce that is left in store at the end of the season.

Experts involved in the preparation of the report on 'Post-harvest Losses in Developing Countries' resisted extrapolating post-harvest loss estimates to global or even to national levels because there would be no statistical ground for doing so (N.A.S., 1978). For planning purpose they mention 10% as a minimum loss for cereal grains and legumes, and 20% as a minimum for perishables. Assuming a total annual cereal production of 450 million tons in 1985, then the United Nations target of a 50% reduction of post-harvest food losses by that year means an increased availability of 22.5 million tons. This target was set by the VIIth Special Session of the United Nations General Assembly in 1975.

Determination of losses which occur at the various stages of the post-harvest system is essential in any programme designed to reduce them. Those parts of the system where losses are highest and where measures could be most effective should be first identified. The size of the losses should determine the effort and expense which can be put into their reduction. Benefits in terms of a decrease in losses should compensate for the costs.

Small farmers are generally very reluctant to change their traditional storage system completely, for instance by the introduction of a metal storage bin. The investment for such a change is too large for them and is not economically feasible (Boxall et al., 1978). Farmers are more likely to try to reduce losses by smaller changes which often involve only a small improvement of their traditional storage structure together with the use of insecticides.

An example of a cost-benefit analysis of such methods is given by Adams & Harman (1977). Such an analysis should be made not only for the individual farmer but also at national level. The social benefits, such as improved food availability or income, can be compared with the cost of subsidies on insecticides and the cost of extension work to stimulate storage improvements. These can then be compared with social and economic costs of importing grain. Boxall et al. (1978) present such a cost-benefit analysis.

To be able to make such studies the food losses with and without improvements in the post-harvest system should be assessed. Methods for the assessment of losses of food grains are described in detail by Harris and Lindblad (1978). For other crops such sophisticated standard methods are difficult to develop due to the diversity of crops, their inherent perishability and the complexity of the marketing and distribution channels (FAO, 1981).

9.2.2 Food grains

To analyse problems in the 'food-path' of cereals and pulses the different stages of the system should be understood (Figure 9). Conditions or activities at one stage can have important influences on the losses that occur in other stages.

The time of harvesting is important for the storage quality

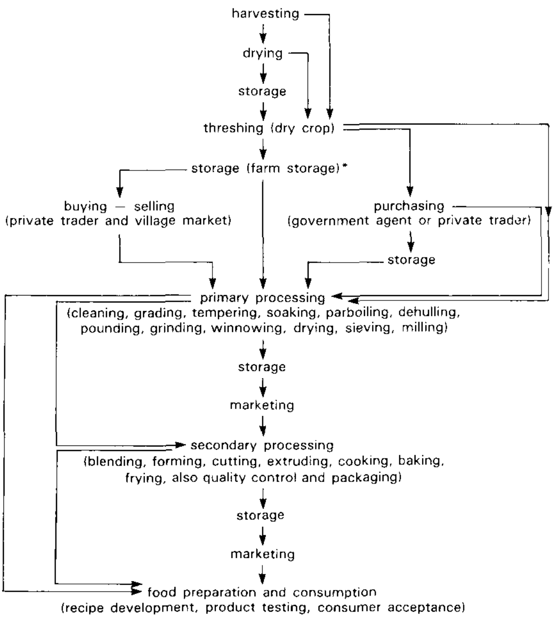

Fig. 9. Flow sheet of food-path for cereals and pulses. (from Spurgeon, 1967; Gasga, 1979) A significant proportion of grain will be prepared and consumed on the farm.

of grain. If maize is harvested when just ripe, it contains too much moisture for safe storage. The crop is usually left standing in the field to dry. Depending on the variety and climatic conditions, this may result in losses due to mold growth and insect attack. Losses due to rodents and birds can also increase in this way.

Traditional threshing and shelling operations may not separate all of the grain from the plant. Some methods do not remove impurities effectively and others may damage or crack the kernels. Damaged grains are more susceptible to insect attack during storage. If grain is processed in the household these problems can be reduced by additional manual cleaning. With mechanised threshing and shelling the losses can only be reduced if suitable equipment is used in the correct way.

Drying problems often occur when crops have to be harvested during the wet season. Artificial drying is necessary in such cases. It is however, a very sensitive operation which requires experience. Too rapid drying and over-drying may cause cracks in the kernel surface which can cause breakage during transport or dehulling. Under-drying may cause microbial spoilage. Selection of the right procedure is therefore very important. Hall (1970) and GTZ (1979) give a theoretical background and information on equipment. The use of wood and oil as fuels should be decreased because of their costs and adverse effects on the environment and the use of solar energy encouraged where possible. Much research in this field is being done by the Brace Research Institute (B.R.I., 1975).

There are biochemical and biological causes for losses during storage. Biochemical changes are for instance:

- production of water, heat and CO_2 by respiration;
- oxidation, causing rancidity.

The biological causes may be:

- micro-organisms, especially fungi which can produce mycotoxins;
- insects and mites that not only eat considerable amounts of food but also cause spoilage because of water migration (heat from the insects causes water to evaporate and condense somewhere else in the store);
- rodents and birds.

The training of storekeepers may be more effective at reducing losses in large stores than the introduction of technical improvements. Large silo storage is capital intensive and may cause technical and management problems. Problems such as dust explosions, spontaneous combustion, caking and bridging of produce can arise. Bag storage in warehouses is easier to manage and more flexible in use, but the storekeepers need a good training in store hygiene and warehouse management.

On the farm traditional practices are not always adequate for storing new varieties. High yielding maize varieties for instance, are more susceptible to insect, rodent and bird attack because the husk does not completely enclose the grain as it does with traditional varieties. Insecticides are becoming more generally available in developing countries and their use is necessary to reduce losses. The successful application of insecticide dusts, wettable powders, emulsions and fumigants requires knowledge and care from the farmer applying them. On the other hand traditional pest-control systems are adapted to local circumstances. The use of herbs, admixing of ash, sand or smaller grains, and smoking of grain are effective measures and should be encouraged (N.A.S., 1978).

We may conclude that when tackling grain storage problems, it is necessary to understand moisture and temperature relations and their influence on biological and biochemical deterioration. Principles of drying, and methods of moisture content determination and loss assessment should be known. Finally the 'why' and 'how' of traditional practices should be appreciated.

9.2.3 Other products

Fruits and vegetables are more susceptible than grains to mechanical injuries, and loss of water and quality because of respiration. The storage of climacteric fruits gives special problems because of their respiration rates and the production of ethylene that stimulates ripening. For fruits and vegetables the time between harvest and consumption should not be too long. The actual keeping quality depends on the kind and variety of plant. Stem vegetables and thick-leaved vegetables can be stored for periods ranging from several days to some weeks depending on storage conditions. Thin-leaved vegetables can, even under optimum conditions, only be stored for a few days. The species and maturity of a fruit affect the safe storage period. Roots and tuber crops are generally easier to store if they have a dormancy period, and some are suitable for long term storage.

Cooling, refrigeration and atmosphere control are important storage techniques that decrease all types of deteriorative reaction. Controlled atmosphere storage decreases the amount of oxygen available for respiration. A general publication on the prevention of fruit and vegetable crop losses was prepared by the FAO (1981).

9.2.4 Research and extension

Research should take the whole post-harvest system into account and be based on loss assessment surveys. Such efforts need to be co-ordinated at national level. In general the following are the most important needs for research and development (N.A.S., 1978):

- improved milling, drying and threshing;
- low-cost cooling systems;
- research on pesticides with particular reference to their safety in use in foodstuffs, their environmental consequences and their use in combination with other loss prevention methods;
- especially for commodities with a short storage life.

It must be stressed again that at farm level, self sufficiency is in most cases more important than production for the market. Security is the basis for many actions of small farmers. Any improvement in the post-harvest system should show a cost-benefit ratio in favour of the farmer. With regard to security, community-level storage systems need special attention (Burke, 1976) and a critical analysis of their value to individual farmers and the community should be made.

When selecting a technique one important criterion is the employment effect for village artisans and lower social groups. According to Greeley (1978) this employment aspect should be part of any post-harvest programme evaluation. It must be possible to turn any proposed improvements into economic, social and cultural realities.

9.3 ENERGY AND WATER SUPPLY

In many food processing operations some form of energy is required: mechanical energy for the milling of cereals and pressing of oil-bearing seeds and heat energy for drying and heat preservation. Rural energy is very important for supporting employment generating activities and stimulating development. The organisation of energy supply programmes affects who will actually benefit from such programmes.

World fossil energy resources are limited and expensive.

Regular transport of fossil fuels and transmission of electricity to rural areas is difficult. The use of wood as an energy source can cause environmental problems such as soil erosion. It is therefore necessary to pay more attention to other renewable energy sources.

A good overview of existing technologies for solar and biomass energy, wind and water power, internal and external combustion engines and electricity generation is given by Fraenkel (1979). Stassen (1980) has also written an excellent overview, which discusses economic considerations and gives a comparative evaluation of renewable energy resources.

Wood stoves are more efficient and consume less fuel than an open fire, but their successful introduction must be preceded by studies of the cooking habits of women. Solar cookers are in general still too complicated to be of general use, but they are being tested and promising results with bread baking have been achieved in Botswana (Curruthers et al., 1979). The solar water heater proves in practice to be attractive. Solar fruit and vegetable dryers look promising but are not yet widely used. Methane fermentation may be an option for rural areas, but it requires a relatively difficult process control. Wind power is (in suitable areas) a promising source of energy for activities such as pumping water for drinking or small-scale irrigation and cereal milling. The small amounts of water required for drinking can be lifted from deep lying water reserves by the use of windmills, but for irrigation purposes the higher flow rates necessary can only be attained if the delivery head is smaller. When the air velocity is 3.5 m/s, a five meter diameter windmill can pump 4.4, 1.6 and 0.6 m^3/h from delivery heads of 7, 20 and 60 meters respectively. The direct combustion of by-products and waste material has been the most important source of energy in many agro-based industries. The anaerobic treatment of waste water from food industries may provide an additional source of energy (Lettinga, 1979).

Water is an important auxiliary in many processing operations for example, for transport and cleaning of raw materials and as steam for power or heat transfer. A constant supply of water of good hygienic quality should be available and even for small food-processing units an individual well or borehole may have to be built. Cairncross & Feachem (1978) give an overview of technology for small water supplies. A shortage of water or environmental problems will usually require the recycling of process water and treatment wastes.

9.4 BY-PRODUCT AND WASTE UTILISATION

An agricultural by-product or residue can be defined as the material left over from the production and primary processing stage (Aten, 1979). It may come from all agricultural products; food grains, fruit, vegetable, poultry, meat, fish or dairy products. Some residues are recognised to be valuable. Groundnut cakes from oil processing industries are used as an animal feed. Bagasse, a by-product of sugar processing from sugar cane, is a valuable source of energy for the sugar production plant, but other by-products do not at present appear to have any economic value.

In many cases these products cause environmental problems. On small farms the composting of animal waste and agricultural material with a high carbon and nitrogen content offers an opportunity to recover and re-use part of the value of these wastes. Intensive animal rearing however may cause pollution and health problems. Large amounts of wastes, such as the sludge from palm-oil factories, may cause surface water pollution.

These problems have been recognised by the FAO who organised a seminar on residue utilisation in January 1977: "Management of Agricultural and Agro-Industrial Wastes". Several interesting papers were presented, especially those of Tetefort (1977), Patel (1977) and Sczcepanik (1977). A world-wide list of institutions which work in the field of residue utilisation was prepared by Barreveld (1978a), who also published an important compendium and bibliography of available technologies for residue utilisation (Barreveld, 1978b).

From the FAO compilation of technologies it may be seen that many processes are available for utilising wastes, but at present energy costs outweigh the profits obtained from the value of the products. Rising animal feed prices, production of single cell protein and pollution taxes in some countries make waste treatment more feasible. Food industries have a special problem, because the amount of waste water and the kind of waste may vary both with the time of year and the time of day (Tetefort, 1977). It is difficult for these industries to apply continuous processes essential in many waste treatment methods.

Energy supply is an important service for waste processing. Especially in rural areas energy from waste may add to the energy supply and reduce dependence on other resources. If, for instance, wood is an important fuel a reduction in the requirement for firewood will prevent further soil erosion. Although anaerobic digestion is not a technology that can be applied easily (see Van Brakel (1980) for the long history of this technology), there are many positive experiences with methane production from waste. Patel (1977) discusses solar heated, anaerobic digesters for night soil and water weeds:

'Anaerobic digestion yields both fuel gas and organic fertilizer with minimum loss of plant nutrients contained in the original material.

Further the small anaerobic digesters, known in India as gobargas plants are well received. We had 7000 plants up to 1974. Now there are more than 30,000 plants and the rate of installation is increasing. These are family level plants. A majority are made to produce from 4 to 10 cubic meters gobargas.

The present position regarding electricity for villages is miserable. A few pockets, mostly near urban centres are electrified. There is no hope of small distant villages getting electric power for the next 5 years or more. It is no secret that rural electrification from central sources is uneconomic due to various reasons. Village level gobargas plants however are shown to be technically feasible and economically paying as any commercial enterprise may be'.

Patel mentions that the social and political circumstances are important for the success of the introduction of the new technology.

Sczcepanik (1977) states more generally that it is necessary to examine each case on the social acceptability of the product, the economy of its production and distribution including the social costs of untreated waste accumulation and disposal. Serious health hazards may arise from human waste in urban areas, therefore there is a need for treatment plants. Microbial protein, produced from waste materials, does not seem to be a realistic source of food or feed. It is the lack of purchasing power not of food which is the central problem, especially in Africa. Food shortages must be met primarily by changes in the agricultural pattern and by the improved supply of primary products rather than by indirect supply of animal protein.

The construction of waste treatment plants is related to tax laws, investment incentives, and the cost of capital.

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10 Choice of food processing technology

The approach to the choice of processing technology presented in the previous chapters can best be explained by giving a few examples of the processing alternatives available for the processing of a number of raw materials, and the factors which should be taken into account in evaluating these alternatives. In the following chapters therefore, the processing of sugar cane, cassava and maize is discussed. In these examples we aim to give a general description of available technology and to present criteria for choosing suitable products and processes, rather than to give detailed studies of decision-making in specific situations. Complete generalisations about the choice of a technology are however difficult to make because every situation has its own specific requirements and socio-economic, cultural and political criteria are by their nature closely related to specific countries and situations.

The example of sugar cane processing is mainly based on material from India and Bangladesh, the evaluation of maize milling technologies is based on material from Kenya and Nigeria, while the information about cassava starch processing comes mainly from South East Asia, in particular from Indonesia. The evaluation of technologies for the production of gari from cassava is a more specific case from Nigeria.

In describing alternatives for processing a certain raw material, one can consider all the possible products and by-products that can be derived from it. This leads to what may be called a "product spectrum". The available range of technologies for manufacture of the most important products can also be made. For each product this leads to a "spectrum" of technologies and scales of production. In the next three chapters the market situation and product spectrum of the three commodities are discussed. Only for the most important products are the different levels of technology described and evaluated ("technology spectrum").

For sugar cane processing, emphasis is laid on the available range of technologies for producing sugar. These are not completely comparable, because one of these technologies (gur production) gives a less refined product with other marketing characteristics.

The different levels of cassava starch production are more comparable because there is less difference between the end products. The starch processing alternatives will be discussed in detail, with a short discourse on chip and pellet production as an alternative that competes for the same raw material. Various methods for the manufacture of gari, a fermented product for human consumption, are also discussed.

The number of possible uses for maize is very large and these cannot simply be compared. An overview of the product spectrum is given, but the emphasis is on comparing different dry milling techniques. Whatever variations there may be in the preparation of foods from maize, one operation common to many dishes is the milling of maize flour, either by wet or dry methods. Even if the maize is intended for animal feed or for industrial purposes (e.g. the manufacture of starch, modified starch, glucose, brewer's grits or maize germ oil), size reduction is an important initial operation.

These processes have been chosen for the next three chapters, because of the experience of the writers with them and the availability of published literature. Sugar cane processing serves very well to illustrate different methods for the extraction of sugar because small- and medium-scale technologies are available, next to the usual large scale capital intensive methods. Cassava and maize are both important staple food crops that deserve attention, especially because of the need to increase the labour productivity and improve traditional technologies in many rural areas. Increasing urbanisation, division of labour and specialisation in the agricultural sector are additional reasons for studying new technologies for cassava processing and maize milling.

Other staple foods and oil seeds also deserve attention, and therefore in Chapter 14 some important literature sources are quoted to assist the reader in the selection of technologies for these commodities in the manner proposed in this book. References on products, such as meat and fish, milk, fruits and vegetables, spices and essential oils, are also given in Chapter 14. These products are however mostly for local consumption and are consumed fresh. It is therefore difficult to write comprehensively on preservation technologies for this diverse range of commodities. For specific cases the systematic approach to the choice of technology should be used.

11 Sugar cane

11.1 SUGAR CANE CULTIVATION

The cultivation of sugar cane (Saccharum spp. L.) dates back to the 4th century when it was grown in India. Gradually its culture spread over the world and by the 15th century it was found in China, Persia and the eastern Mediterranean, North and West Africa, Brazil and the Carribean. In the early days cane was used only for chewing, but in India production of jaggery from palm juice was already practised and the first production of sugar from cane juice developed there.

11.2 SUGAR PRODUCTION AND USE

11.2.1 Production

The following basic steps can be distinguished in the production of sucrose from cane (Fig. 13). Juice is firstly extracted from the cane. The extracted cane termed bagasse is normally used as fuel in further processing. The juice is then clarified and the impurities are removed in the scums or mud. The clarified juice is concentrated until crystals form. Except in the simplest processes, crystallisation is followed by separation of crystals and molasses, and further drying of the sugar.

Some sixteen centuries ago, sugar cane was processed in a simple way, namely by pressing out and concentrating the juice. This in fact is still done on a small scale in many tropical countries, for example, India and Indonesia. The products of this process are known as gur, jaggery, gula jawa, panela, chacacca and by other local names. Between the 8th and 10th centuries the cultivation of sugar cane also came to the Mediterranean countries. During that period sugar refining was developed in the Arab civilisation. The growing of sugar cane was later transferred to South and Middle America where it became a very popular commodity (Yudkin, 1971).

The earliest mills were probably mortar and pestle arrangements. Later on screw and lever presses were widely used for juice extraction until these were superseded by the roller mill invented by a cane grower in Sicily in 1449. Animals, water wheels and windmills were used to power these roller mills. Steam power was first used in Jamaica in 1768.

Until the 19th century sugar cane had been processed on a very small scale. In the 19th century the modern industrial process was developed, influenced by two important inventions. In 1813 the invention of the vacuum pan made crystallisation possible at lower temperatures and pressures thus reducing the loss of sugar by inversion. Later, in 1846, multiple effect evaporation was developed, reducing the energy requirement for evaporation.

11.2.2 Uses

The main use of sugar is for human consumption. Sugar has both positive and negative influences on human Nutrition (Morel, 1977). The positive

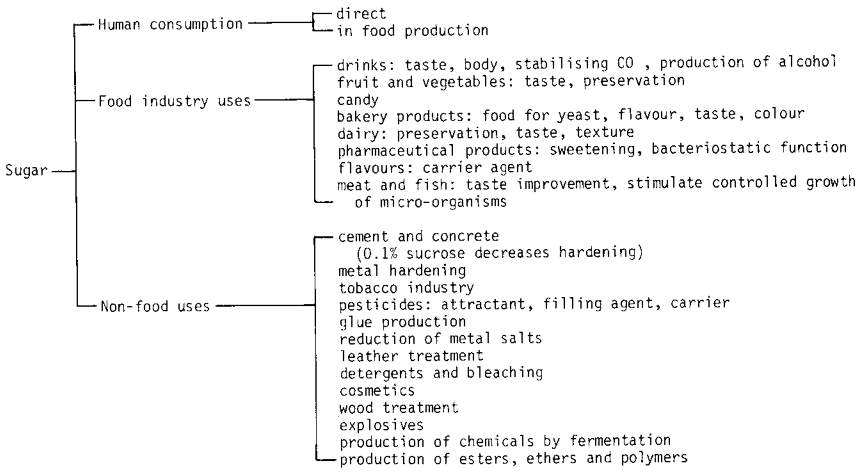

Fig. 10. Uses of sucrose. (from Kort, 1977)

aspects are:
- preservation of foods;
- sugar is the cheapest energy source in the diet (16.8 kJ/kg);
- because of its ability to improve the taste of other products sugar is able to make more nutritious products attractive and stimulate their consumption.

The negative aspects are:
- heart and vein diseases: sugar and other carbohydrates raise the triglyceride level of the blood;
- there is a relationship between sucrose consumption and the development of caries (this is also associated with food habits, amount and frequency of eating sugar or sugar products, and mouth hygiene).

In Figure 10 an overview is given on the uses of sugar in food as well as non-food industry.

11.3 WORLD MARKET

In western countries sugar has always been a very expensive commodity. This influenced the development of beet sugar production although it is a considerably less efficient producer of sugar per hectare than sugar cane. Only since the second World War has the production and consumption of crystal sugar substantially increased (Yudkin, 1971). The sugar consumption per head of population is about 20 kg per year as an average for the whole world. In rich industrialised countries the consumption is about 50 kg per head per year, and in countries like India and China the sugar consumption is less than 10 kg per head per year (Licht, 1979). The consumption of other sweetening agents such as locally produced gur is not included in these figures and in India consumption of gur is higher than that of crystal sugar.

Total world sugar production increases regularly each year by some two million tonnes. Sugar cane contributes 60% and sugar beet 40% to this growth (Licht, 1979). This means that the crushing capacity for cane must expand by 8 or 9 factories per annum, each with a capacity of 6000 tonnes of cane per day. Figure 11 shows that production and consumption do not differ greatly. About 70% of the total production is consumed in the producing countries themselves. Only 30% of the total production comes on to the world market and half of this amount is traded by preferential agreements (Terberg, 1977).

As only 15% of the total world sugar production comes on to the free market, small differences in production and consumption cause large variations in price. Figure 12 shows the price movements on the world market of

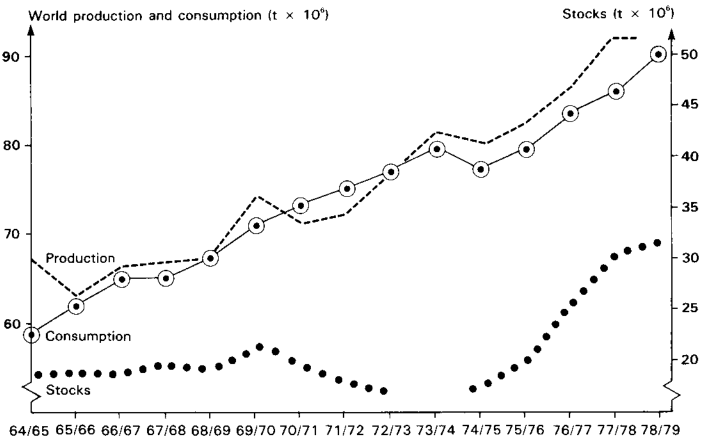

Fig. 11. World production, consumption and stocks 1964/65 - 1977/78. (from Licht, 1979)

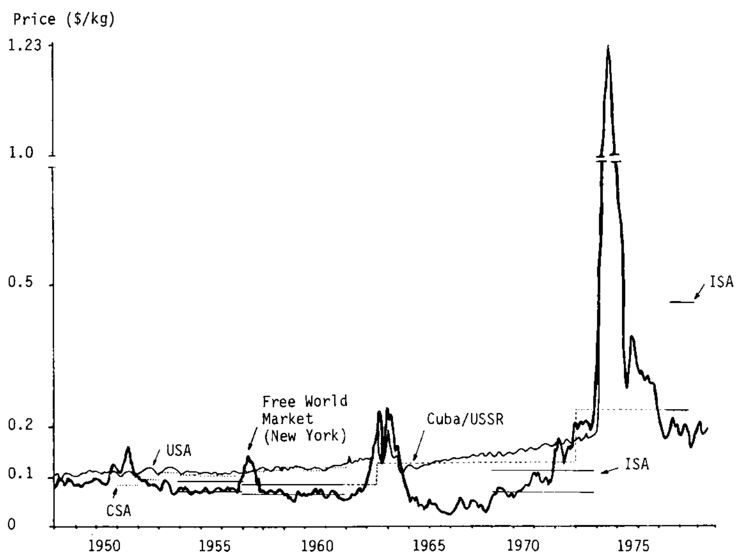

Fig. 12. Price fluctuations for raw sugar on the world market and some preferential markets 1948-1979. ISA = Intern Sugar Agreement price margins. (from Licht, 1977 and 1979)

sugar and the prices negotiated by some preferential agreements. The US Sugar Act set a stable price mainly for US producers until the world energy crisis in 1974. The International Sugar Agreement (ISA) supports maximum and minimum prices for the producing countries. Since 1978 basic export quota have been agreed for each two year period. In this way the agreement tries to stabilize the market.

The following predictions for the course of the sugar market in the immediate future have been made (Terberg, 1977):

(1) Rich countries importing sugar are expected to expand their own cane and beet production. They will also produce more High Fructose Glucose Syrup which can be used as a sweetening agent in food industries and bakeries. Imports from the world market will only be required to balance supply and demand.

(2) In poor sugar exporting countries, the national sugar consumption is expected to increase due to a rise in income and population growth. Exports will fall because of this and also because of the decreasing demand from rich countries. FAO projections up to 1980 and 1985 suggest an average increase of 15.7% and 32.2% respectively over the 1975 levels of world demand. When broken down by region, however, the increase is heavily concentrated in the developing regions. In 1985 demand is projected to increase by 69% over 1975 levels in Asia, 57% in Africa, 58% in the Near East, 55% in the Far East and Oceania, and 41% in Latin America.

(3) In poor countries importing sugar, the sugar consumption will also tend to increase, but importation will become difficult with the declining world market. Higher sugar prices will make the national production of sugar more profitable.

To satisfy the increased demand for sugar large areas of sugar cane will have to be planted. If large-scale factories are to be used to refine sugar then extensive plantations will be required in their vicinity. Large areas suitable for sugar cane cultivation are not available in every country that wants to increase its sugar production without making considerable investments in irrigation systems. Even where large dams are planned the soil may be unsuitable for sugar cane. Smaller, more scattered areas are however often still available. The expansion of production has to take place either on less appropriate soils or in more scattered areas. This is one of the main reasons for the growing interest in smaller processing units. The existing level of unemployment in many rural areas also favours labour intensive technologies.

To illustrate the existing range of technologies, four processes will be described:

- large-scale factories with a capacity of 1000 to more than 20 000 TCD (tonnes cane per day);
- mini sugar cane factories with a capacity of 300-800 TCD;
- Khandsari or open pan sulphitation with a capacity of 50-200 TCD;
- gur production with a capacity of a few hundred kilograms cane per day to 15 TCD.

11.4 LARGE-SCALE FACTORIES

11.4.1 Process description

The large-scale process is essentially the same for capacities varying from 1000 to more than 20 000 TCD. Figures 13 and 14 illustrate the sugar production process schematically. The most important references for this description of the large-scale process are Hugot (1972) and Meade & Chen (1977). The cane is mostly mechanically harvested, but it may be cut by hand.

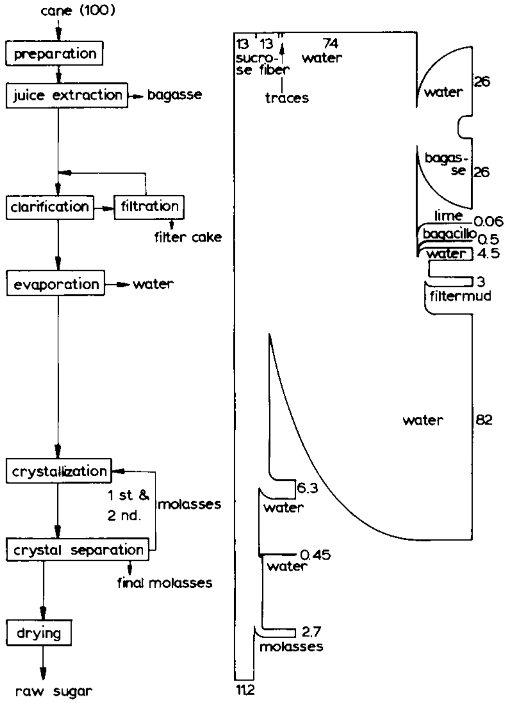

Fig. 13. Flow sheet and mass balance of raw sugar process. Numbers represent examples of the mass balance, expressed in % (1% = 10 g/kg).

Transport to the factory over an average distance of 12 km is by rail or truck. After storage for at the most 12 hours the cane is washed with 5-6 tonnes of water per tonne of cane (this amount can be larger or smaller under differing harvesting conditions.

Prior to juice extraction, the cane is prepared by cane knives, shredders and crusher rolls. In this way the cells are ruptures to improve juice extraction. In modern well-managed installations, up to 90% of the cells can be opened by this preparation. The juice is then extracted by expression from the fibre in a milling tandem with normally 4 to 6 three roller units. Water is added in a counter current system to the bagasse to get a better sugar extraction (imbibition water). In this way it is possible to obtain a milling efficiency for sugar of maximally 97%.

Juice extraction can also be carried out in diffusers. In this system a layer of prepared cane is extracted by percolating water. The diffuser is followed by one or two mills which press the juice from the bagasse. For both milling and diffusion, the by-product of the extraction process is bagasse which is generally used as a fuel for the boilers.

The choice between a tandem of mills and a diffuser is not easy to make and factory managers with experience with one of these will not readily change to the other. For new projects the following points should be considered:

(1) If the cane is prepared well (i.e. 90% of the cells are broken) both

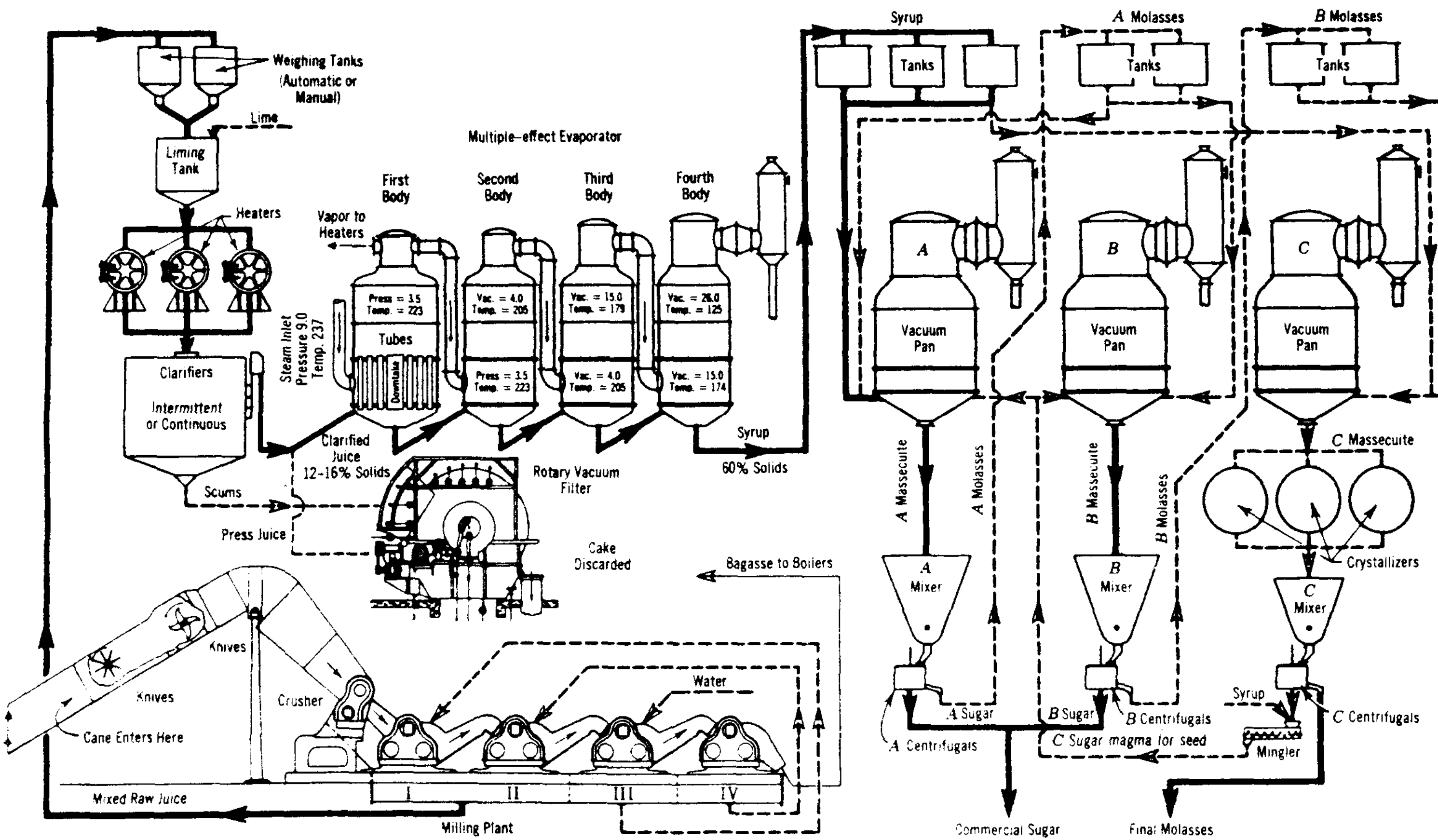

Fig. 14. Process diagram of a large-scale raw sugar factory. (from Meade & Chen, 1977)

technologies result in about the same total sugar recovery. Although the extraction efficiency may be higher for a diffuser, this technique gives a lower recovery at the crystallisation stage.
(2) A diffuser and two connecting conveyor belts can in a conventional tandem of 5 to 6 mills replace 3 of the mills, but it normally requires more space. The investment is comparable with that for 2 to 2.5 mills.
(3) A diffuser combined with 3 mills uses only slightly more than half of the energy required for a series of 6 mills.
(4) Because a diffuser produces a clearer juice less sludge is produced and a smaller filter capacity is required.
(5) A diffuser needs less maintenance and replacement of components. Mills require regular replacement of the cylinders, conveyor belts and parts of the steam driven engines.
(6) The operation of a diffuser needs more skilled engineers because of the critical process control. The longer contact of the juice with the bagasse in a diffuser causes two main problems: (1) a lower pH will result in more inversion of the sugar and (2) a higher pH, caused by the addition of lime, in combination with a higher temperature (70 ^{o}C) will impede crystallisation because the conditions favour dissolution of pentosans and waxes.

The fresh juice is weighed and the sugar content measured. The acid juice needs to be neutralised by adding lime and by heating it to 104-107 ^{o}C the proteins and some of the fats, waxes and gums are precipitated. A better clarification can be carried out by sulphitation and carbonation. For this purpose CO_2 from the flue gasses of the boiler or from a lime kiln is bubbled through the neutralised juice. After the mud settles it is filtered and washed with water in a filter press or rotary vacuum filter.

The clarified juice with a concentration of 110-160 g sucrose/kg pure sugar solution (1 g/kg = 0.1 ^{o}Brix) is concentrated to syrup of 600-700 g/kg in a multiple effect evaporation system consisting of 3, 4 or even 5 effects. Further concentration follows in vacuum pans until "A" crystallisation at 700-800 g/kg takes place. The syrup is concentrated to supersaturation and then powdered sugar is added to assure a controlled crystallisation with even sized crystals being formed. The massecuite is cooled for further crystallisation and the crystals are removed from the mother liquor (or molasses) in batch or continuously operating centrifuges. The mother liquor is boiled for a second time and after "B" crystallisation for a third time. The sugar formed at the third stage consists of very small crystals and is used as seed sugar for the crystallisation of "A" and "B" sugar. The molasses from the third stage is a by-product of the process. The "A" and "B" sugar contain about 1% (w/w) moisture and must be dried to 0.1% moisture to get a good keeping quality.

11.4.2 Mass balance

The mass balance of the process is illustrated in Figure 13. Sugar cane contains 12-15% (w/w) sucrose and 11-16% fibre. The rest is mostly water with some traces of protein, wax, fat and minerals. The amount of imbibition water added during milling is normally equal to twice the amount of fibre. Bagasse contains 47-52% fibre, the rest is water and soluble solids such as sugar. To neutralise the juice 0-5-0.8 kg lime per tonne cane is used. The water for washing the filter cake is 1.5 times the amount of cake. Most water is evaporated in the multiple effect evaporators, but a smaller amount is lost during crystallisation. To remove sticky molasses from the sugar crystals, a small amount of steam or hot water is added during centrifugation. The by-product, molasses, is 2.2-3.7% of the cane weight and contains 17-25% water, 30-40% sucrose and 10-26% reducing sugars. The sugar yield is about 0.11 tonne per tonne of cane.

Losses of sugar occur during the whole process starting from harvesting. The hydrolysis of sucrose to invert sugar, an equi-molar mixture of glucose and fructose, is accelerated by an acid environment, high temperatures and the enzyme invertase. In most harvesting systems, the cane leaves are burned to diminish the amount of trash and to give easier access to the cane for cutting. By burning, frost or storm the cane can be damaged so that inversion starts within the damaged cells. The mixture of fructose and glucose is very difficult to crystallise and is lost in the molasses.

Losses of sugar can also occur through the growth of the bacterium Leuconostoc mesenteroides, which multiplies in damaged cane at higher temperatures and neutral pH. It produces dextran from sucrose, which raises the viscosity of the juice, hinders purification and delays the crystallisation.

11.4.3 Energy

The total energy demand of the process depends on the equipment used. Mills require more energy than a diffusor and a multiple effect evaporator with three stages needs more steam than an installation with five stages. The down-time of the factory also plays an important role in this calculation.

For example a triple effect raw sugar factory needs 500 to 600 kg steam to process 1 tonne of cane. This quantity is distributed as follows:
- 10-20% for pumps, mills and electricity;
- 70-78% for evaporators;
- 1.2-3.3% for heat losses;
- 0.1-7.3% for juice purification, varying with the system used;
- 9.7-13% for condensate losses.

Bagasse, coming from the last mill with a moisture content of 48% (total weight basis), is used as fuel for the boiler and produces on average 2.35 kg steam per kg bagasse. Raw sugar production therefore needs 200-240 kg bagasse per tonne of cane. From each tonne cane 220-320 kg of bagasse is produced, leaving a surplus of not more than 120 kg bagasse per tonne of cane. This surplus is not normally realised because it depends on the percentage of fibre in cane and the furnace efficiency. The furnace efficiency is related to the dimensions of the bagasse particles, distribution of bagasse in the fibre, preheating of the bagasse, the quantity of dirt in the bagasse and its moisture content. The correct moisture content is particularly important; with a moisture content of 48% bagasse burns well but at 52% it burns poorly. Furnace efficiency may be decreased to get rid of the excess bagasse. When however, there is an urban centre near the factory, surplus electricity may be produced if this was foreseen during factory design.

11.5 MINI CANE SUGAR FACTORY

This type of factory, with a capacity from 300 to 800 TCD, designed for smaller cane growing areas. The process is a simplification of the conventional large-scale sugar extraction method but more labour is used, for instance for cane loading. The process is described by the same flow sheet (Figure 15) and it differs from the large-scale process in the following details. The most important references for small cane sugar factories are DDS (1979), Interplan (n.d.) and Mukherji (1977).

Only three mills are used with imbibition water applied on the second and third mills. About 10% of the sugar is lost in the bagasse, which has a moisture content of 50-52% and can be used in the boiler house. After heating the juice lime is added just before clarification. The mud is fil-

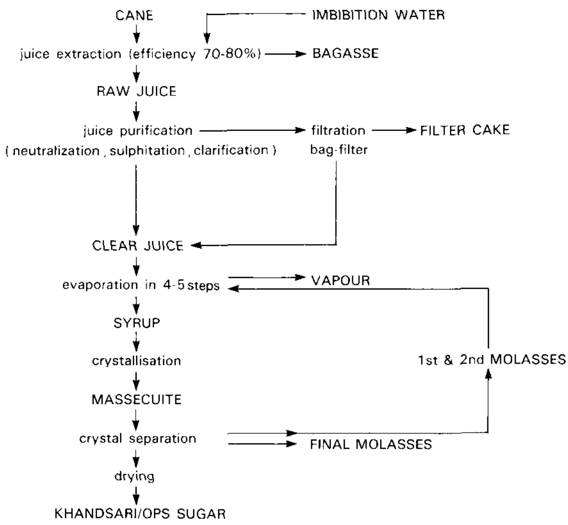

Fig. 15. Flow sheet for open pan sulphitation or Khandsari process.

tered in filter presses, which are more labour intensive than vacuum filters. The juice is concentrated in a two stage evaporation system to 600 g/kg. In this system each kg steam can evaporate nearly 2 kg water. Crystallisation takes place in only two stages. Cooling and centrifugation are batch operations. The overall recovery is estimated as 72% of the available sugar content, which corresponds with 0.91 tonne of sugar from 1 tonne of cane.

11.6 KHANDSARI OR OPEN PAN SULPHITATION

The process for making Khandsari sugar has been developed from an old Indian cottage industry. Since 1950 research has been done in India to improve the efficiency of this process.

The most important difference from the larger scale processes is the evaporation process which takes place at atmospheric pressure. As clarification is by sulphitation the process is also called Open Pan Sulphitation (O.P.S.). In comparison with a multiple effect installation, more energy is used. On average the amount of bagasse produced is not sufficient, and 10% additional fuel, usually in the form of firewood, is necessary. The flow sheet of the process shown in Figure 15 comprises the following operations (Garg, 1980):

- Juice extraction in two or three roller mills driven by a diesel engine with imbibition water added before the second mill. After extraction, 20-30% of the sugar remains in the bagasse.
- Juice purification of raw juice by liming and sulphitation is followed by settling. The mud and scums are separated in a simple bag filter or filter press.
- Evaporation of clear juice takes place in 4 or 5 steps in open pans (atmospheric). From the first to the last step the boiling temperature increases.

- Crystallisation occurs during slow cooling of the syrup over 24 hours. The mixture of crystals and molasses (massecuite) is stirred intermittently by hand.
- Crystals are separated from the molasses in batch centrifuges. The molasses are boiled for a second and third time to produce more sugar.
- Crystals are dried in rotating drum driers or in the sun.

Khandsari sugar can be produced in factories with capacities varying from 50 (Sharma, 1978) to 200 TCD (Garg, 1980). A higher output is not possible because the process is so labour intensive. The bagasse must be dried in the sun before it can be used in the furnaces. Bagasse is transported manually, an operation which limits the maximum capacity of a plant because of the difficulties in organising the work force. For a 100 TCD factory about 163 daily labourers mostly unskilled are needed. The rest of the staff consists of 39 people of whom 9 are permanent and 30 seasonal.

11.7 GUR PRODUCTION

Gur is produced by individual farmers or at village level on a small or intermediate scale. The process has been known for many centuries and the product in fact is concentrated cane juice. The process is illustrated by Figure 16. A general description can be found in RTI (1977), and RTI (1979).

The power for crushing is supplied either by bullocks or an internal combustion engine. Motor-powered crushers can handle more cane than animal-driven mills and operate with greater efficiency. (Motorised crushing gives a maximum of 2 tonnes per day, 65% of juice extracted. Animal powered crushing gives a maximum of 1.2 tonnes per day, 60% of juice extracted). The final yield of gur from the motorised operation is 110 kg gur per tonne of cane in comparison to 100 kg gur per tonne of cane from animal-driven mills.

In Asian countries, the bagasse is generally used to fire the evaporation furnace. In Africa wood is sometimes used for firing. Before the bagasse can be used for firing it must be dried in the sun. The juice is concentrated in one step by open pan boiling. During boiling the juice is clarified by skimming of impurities. To improve the clarification traces of herbs and plants or other agents such as milk of lime are added. After the required concentration (the striking point) has been reached, the mass is poured into forms to set. Good crystallisation can be promoted by cooling rapidly in a flat trough and stirring before filling into the forms. Sometimes balls are formed. After handling the gur becomes available as big lumps of brown sugar. Because few impurities have been removed, the gur contains practically all

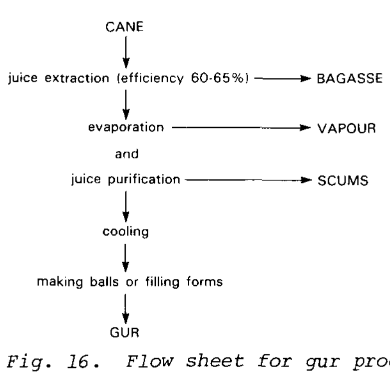

Fig. 16. Flow sheet for gur production.

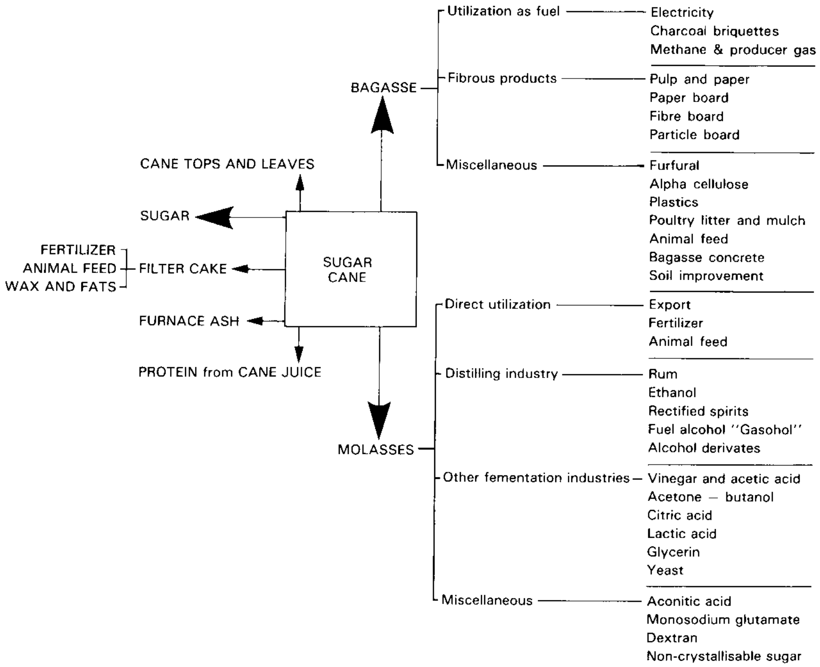

Fig. 17. By-products of the cane sugar industry. (from Paturau, 1969)

the material originally present in the cane juice. Gur contains 4-8% (w/w) moisture, 90-95% carbohydrates (sucrose (73-80%), glucose and fructose), 0.5-1.5% mineral matter (mainly calcium and phosphorus) and traces of proteins, fat and vitamins. Because of these impurities, gur is hygroscopic and does not keep well in humid conditions.

In India much research has been done on improving the evaporation (Roy, 1951). Modern Khandsari production systems are a combination of improved gur production methods and modern sugar technology.

11.8 BY-PRODUCTS

Figure 17 presents the various potential by-products of the sugar industry. Further processing of by-products naturally receives more attention when production costs in the sugar industry increase and when sugar prices decrease. However, some comments should be made about the economic feasibility of by-product utilisation (Paturau, 1969 and 1976).

- The local market for the by-product must be large enough and the government must be willing to protect this market for a certain period from outside competitors.
- For most processes the level of surrounding industrialisation and infrastructure needs to be high.
- The price of by-products is related to alternative products. One tonne of bagasse for instance, has the same heating value as 0.34 tonnes of oil. The

Table 5. Sugar recovery of different production processes.

	Large scale[1]	Mini factory[2]	OPS[3]	Gur[4]
Milling recovery				
After juice extraction (%) (w/w)	95-97	90	70-80	60-65
Total sucrose recovery (%) (w/w)	80-85	72	57-64	44-52
Total sugar output				
t sugar/t cane[a]	0.112	0.91	0.7-0.8	0.10-0.11

Sources:
1. Meindertsma, 1977; Paturau, 1969; Meade & Chen, 1977
2. Baron, 1975
3. Garg, 1976; Paturau, 1969; Bodewes, n.d.
4. Royal Tropical Institute, 1979; Pers. Comm. Korthals-Altes, 1981; Anon., 1977

a. Cane with 13% (w/w) sugar and 13% fibre is considered.

world demand for molasses is high and the price offered good. The price of scums is related to that of an equivalent amount of fertilizer.
- Economics of scale play an important role in the earning capacity of different processes. Utilisation of by-products will therefore be economically more attractive with increasing scale of processing of sugar cane. It is however, not easy to give minimum capacities for different processes. These depend on too many factors. For instance, minimum capacities for paper pulp production vary from 10 to 350 tonnes of pulp per day. The market can be a limiting factor as can the availability of raw material; the amount of surplus bagasse depends very much on the energy efficiency of the process.

11.9 EVALUATION OF TECHNOLOGIES

Comparison of the four processes (Table 5 and Figure 18) indicates a decreasing sugar extraction efficiency going from large-scale sugar processing to gur processing. The total sucrose recovery also decreases. However, in gur the invert sugar also remains in the product. This comparison only concerns sugar recovery, but when choosing a processing technology many other factors are important. A comprehensive evaluation should follow the basic decision-making scheme shown in Figure 2.

11.9.1 Problem and target group

An accurate definition of the problem requires a thorough analysis of it. When the problem is formulated from a purely technical point of view, the solution proposed does not necessarily meet all the requirements of its users. If a new technology is to be introduced into a village the existing processing tradition should be considered and should the target site be a factory then current practices have to be investigated. At the same time socio-economic aspects of the processing operation should be studied.

The main target for cane processing must be clear. Is sugar production for the local market or for export? Is the provision of employment in the factories most important or is it intended to improve farmers' income by providing a good outlet for their cash crop?

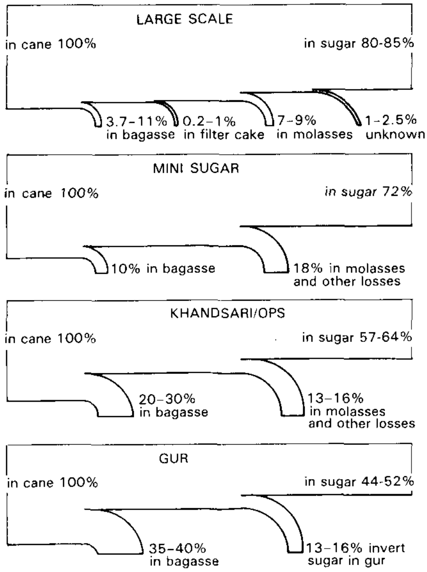

Fig. 18. Sucrose balance for different processes.

11.9.2 Alternative technologies

Two valuable publications which describe and compare existing alternatives are Isaias (1980) and UNIDO (1980), of which the UNIDO-paper is more important.

With the information on the problem and the target group in mind, all alternative technologies which could possibly meet the requirements should be listed. The existing range of technologies is not always large enough and new alternatives may have to be investigated. Small-scale processes will always stay less profitable so long as more research is done on large-scale technologies. With the help of technical, economic, socio-cultural, political and ecological criteria, a selection of the best alternatives should be made. These general criteria may be listed under "musts" and "wants".

MUSTS

Technical

M.1.

The raw material supply, a weak link in many agricultural processing chains, must be appropriate to the processing system. A large-scale industry needs a large area with a monoculture of sugar cane, a good agricultural infrastructure and transport system. The acquisition of land for new plantations means displacing those previously living there. Large areas of uncultivated land suitable for sugar cane cultivation are getting very scarce. Small-scale processing does not need so much raw material and therefore fits into a system of mixed agriculture operated by small farmers (Tainsh, 1975).

Table 6. Comparison of different processes for sugar production (US $).

	INDIA (1973)[1]		EAST AFRICA (1972)[2]		
	VP	OPS	VP	VP	OPS
Capacity (TCD)	1250	80	2000	400	200
Sugar output (tonnes/year)	19000	640	50000	8500	2800
Recovery (t sugar/100 t cane)	9.5	8	10	8.5	7
Crushing season (days)	200	200	250	250	200
Number of workers (fixed and seasonal)	900	171	500	175	350
Investment/year per tonne sugar	191	109	674	453	486
Investment/employee	4018	408	67440	22000	3886
Variable costs/tonne sugar	135	173	204	214	317
Number of workers/100 tonnes per year	4.7	26.7	1.0	2.1	12.5

Sources:
1. Baron, 1975
2. Mukherji, 1977

VP = large scale vacuum evaporation process
OPS = open pan sulphitation process

Economic

M.2.

A meaningful comparison can only be made when the costs of all the different production factors are known for each process. Prices for sugar, bagasse, scums and molasses should be compared with alternative raw materials both at world and local market prices. Most existing comparisons are very incomplete and the results available cannot be generalised as they have value only in a local context at a certain moment. This can be seen from the figures in Table 6. Two such studies however are worthy of mention.

Forsyth (1977) studied processes at four different capacities, each with 20-40 alternatives for the sub-processes (Table 7). Although Hagelberg's (1979) comment that many of the different processing variants do not have any practical value is valid, this study is interesting because it shows the influence of changing labour costs and a change of interest rate on the total profitability of the process.

On the basis of evidence collected mainly from Ghana and Ethiopia, Forsyth (1977) reached some interesting general conclusions. He shows that if 'shadow prices' are used in calculations, profitability in national economic terms may differ from private profitability. Although a new project may appear to be profitable in terms of labour and capital use, it could withdraw goods and services from another sector of the economy and therefore from a national viewpoint it may be less profitable. For small-scale production the most labour intensive processes such as open pan sulphitation are the most profitable. Large-scale production is in general more profitable than smaller operations and is most profitable when capital intensive technology is used (Table 8). Forsyth concludes that it seems to be cheaper to produce sugar on a large scale with a small number of labourers and pay the unemployed people an allowance out of the profit, than to provide work for them in small-scale labour intensive factories.

Hagelberg (1979) criticizes these generalisations with some justice as being valid only in the situations studied, and states that because several technologies are successfully practised all over the world, there cannot be only one universally appropriate technology.

Table 7. Alternative technologies for principal sub-processes. Details of the specifications and manufacturers of the equipment referred to above are available with Fortsyth. (from Forsyth, 1977).

Sub-process	Labour intensive	Intermediate	Capital intensive	Number of variants
Cane weighing	Without automatic recorder	Without automatic recorder	With automatic recorder	2
Cane handling	Manual	Manual	Loaders, cranes Tippers	3
Cane transportation/ feeding	Manual	Manual	Mechanical (conveyors, etc.)	2
Cane preparation	Manual levelling	Manual levelling	Automatic levelling	2
Crushing, milling	Manual Mortar & pestle Small crusher (bullock-powered)	Small crusher (petrol engine powered)	Mill tandem (with automatic controls Mill tandem (with manual controls) Diffuser Abrasion defibrator	8
Clarification	Open-pan sulphitation	Open pan sulphitation	Continuous clarification	2
Filtration	Bag filters	Filter presses	Rotary vacuum filter	3
Evaporation, boiling	Open pans	Open pans	Evaporators/vacuum pans	2
Crystallisation	No forced cooling	No forced cooling	Air cooled, water cooled	2
Centrifugation	Manually driven centrifuge	Manually controlled centrifuge	Continuous centrifuge Automatic centrifuge Semi-automatic centrifuge	5
Drying	Open air	Open air	Cascade dryer	2
Bagging	Manual bagging & closing	Manual weighing, sewing machine	Automatic weighing and closing	3

A second study (Baron, 1975) shows that it is important in economic comparisons to differentiate between long and short crushing seasons. For a crushing season of about 150 days both vacuum pan and open pan sulphitation plants are equally profitable (Table 9) as is shown in Table 9 by the figures for "Present value of costs per tonne sugar produced". At lower social rates of discount however OPS plants are more profitable and this is also true for shorter crushing seasons as can be seen in Figures 19 and 20 respectively.

Economic comparisons, whether presented as feasibility studies or pu-

Table 8. Cost of sugar production at different scales over 25 years, expressed in Ghanean Cedi (₵). Costs are discounted at 10% of the observed prices. (from Fortsyth, 1977)

Output (tonne x 10^3 per year)	Average production cost per year (₵ x 10^3)	Average cost (₵/tonne sugar)	Number of persons employed
50	1720	34.4	1030
25	972	38.9	701
10	500	50.0	435
1	92	92.0	683

Table 9. Socio-economic costs of sugar production. Costs stated in rupees at 1973 value. VP = vacuum pan technology, OPS = open pan sulphitation. (from Baron, 1975)

	VP	OPS
Capacity (TCD)	1250	80
Number of workers	900	171
Length of season (days)	150	150
Tonnes of cane crushed per season	150000	8000
Tonnes of sugar output per season	14250	640
Sugar recovery (%)	9.5	8
Cost per tonne cane	100	100
Total costs of sugar	15000000	800000
Total wages and salaries	2203000	117000
Repairs and maintenance	489000	17020
Other material inputs and overheads	637500	86060
Total running costs per season	18329500	1020000
Present value of total running costs (10% disc. rate)[1]	183295000	10200000
Investment cost	28000000	540000
Investment cost, weighted by the shadow price of investment (= x 2.67)[1]	74670000	1440000
Present value of all costs	257965000	11640000
Present value of costs per tonne sugar produced	18103	18187

1. See explanation with figure 19.

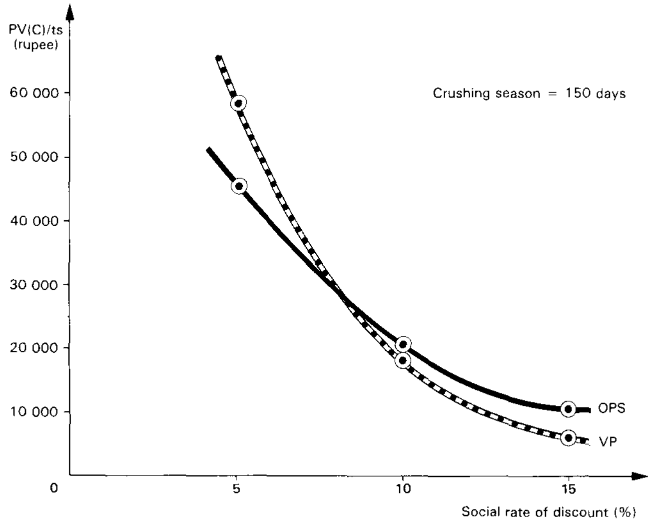

Fig. 19. Social profitability. Relationship between the present value of costs per tonne sugar (PV(C)/ts) and social rate of discount for OPS and VP sugar production. It is assumed that the machinery has a long operational life and that a = r = 0.2 therefore

$$PV(C) = \frac{C}{i} + I\ Pi \text{ with } Pi = r\ (i-a)/(i-ar)$$

C = Total running costs, i = Social rate of discount, I = Investment costs, Pi = shadow price of investment funds, a = rate of reinvestment of profits, r = rate of return on investment in the economy.

blished in some other form, must be treated with caution. The basis for comparison should be clearly defined in terms of scale, labour requirement, initial investment and other relevant data such as crushing season, cane prices, capacity utilization, etc. Bhat & Duguid (1980) in a similar study give more detailed information, but their assumptions and basic information differ from those of Baron. The results of such studies can thus only be used for drawing conclusions in other situations after having made adjustments for a different data base and assumptions.

M.3.

In a small sugar factory or OPS factory there is no surplus bagasse, and the molasses cannot be readily sold on the world market because of the problem of economically transporting such a small quantity of by-product. Molasses and surplus bagasse may be used in large factories for animal feed, board production or alcohol manufacture. The processing of by-products can thus increase employment opportunities.

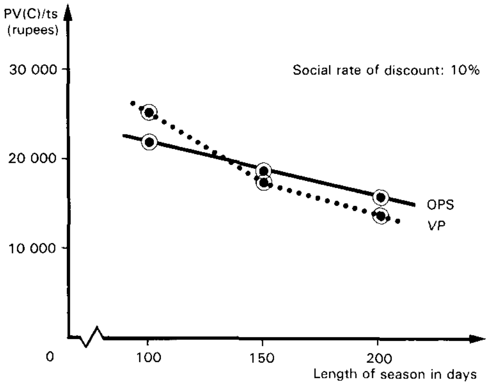

Fig. 20. Relation of PV(C)/ts between OPS and VP technology: the influence of length of the season. See also Fig. 19.

Social

M.4.

In terms of employment and capital costs the figures in Table 10 give a general comparison of OPS and VP technology. Using these figures the sugar output and employment generated from a capital investment of $7 500 000 in both technologies is also tabulated in Table 10.

For such an investment 30 OPS plants can be established against 1 large-scale VP factory. If Forsyth's reasoning is applied to the figures Baron (1975) gives for India (Table 11), it is indeed more profitable to choose the capital intensive technology: there remains in a long crushing season enough profit to give the unemployed labourers an income. The collection and distribution of this money requires an effective taxation and social security system. However, even in countries where there is a good social security system, unemployed people are not likely to be content with a passive role in society.

M.5.

One negative aspect of a labour-intensive technology is that more social provisions, such as houses, schools and clinics are required for (seasonal) labourers and their families.

Table 10. Comparison of OPS- and VP technology. (from UNIDO, 1980)

	OPS plant	30 OPS plants	Large scale plant (VP)
Fixed capital costs (US $)	250 000	7 500 000	7 500 000
Number of workers	180	5 400	720
Sugar output (tonnes/year)	750	22 500	15 000

M.6.

The choice of manufacturing technology must also be related to the consumers quality demands (Table 12). Gur cannot easily be introduced into an area where it was not previously known. And although Khandsari sugar is pure enough to be acceptable for domestic consumption, it should not be overlooked that consumers may choose a more refined white sugar in preference to certain grades of OPS sugar, unless the latter has a price advantage.

WANTS

Technical

W.1.

Qualified personnel for the management and servicing of large-scale sugar extraction plants are not always locally available. The training of local staff should begin as soon as possible, so that they can learn from

Table 11. Social-profitability/employment relation (Indian rupees 1973 value).

	VP	OPS
Invested cost per plant	28 000 000	540 000
Length of season (days)	200	200
Total investment	28 000 000	28 000 000
Number of plants	1	51.85
Number of workers	900	8 867
Relative number of workers unemployed	8 000	-
Running costs/year	19 542 000	44 548 000
Depreciation of investment/year (10% of invested costs)	2 800 000	2 800 000
Total costs/year	22 342 000	47 348 000
Relative costs saved/year	25 006 000	-
Relative saved costs of not emplyed worker/year	3 126	-
(Normal salary/labourer)	(2 450)	(684)

Table 12. Composition (as % (w/w)) of different products of sugar cane. (from Gupta, 1980; RTI, 1979)

	Gur	Khandsari	Plantation white sugar[1]	Raw sugar	Refined sugar
Sucrose	73-80	99.4-99.9	99.5-99.9	97.5-98.5	99.8
Reducing sugars	10-15	0.1- 0.4	0.1	1.0	0.03
Ash	0.5-1.5	1	0.5	0.8	-
Moisture	4-8	0.15-0.50	0.08	0.3	0.05
Colour	brown	yellow/white	white	yellow	white

1. Sugar made directly from cane juices after a specific type of juice purification (sulphitation, carbonation, middle juice carbonation). This sugar is crystallized from boilings with a purity between 80 and 90.

those experienced in the establishment and operation of new plants. In this way there should be no abrupt change when the plant is handed over. The skills required for running a plant depend not only on its scale of operation but also on the technology used. The operation and maintenance skills required for a diffuser process are much greater than for a series of crushing mills.

W.2.

Better sugar recovery can be obtained by cutting and loading by hand as less soil and trash comes to the milling unit. This improves crystallisation and diminishes the amount of mud and the quantity of sugar lost in it (Meade & Chen, 1977). Sugar recovery is also increased by extraction of the pressed cane with water. More water must then be evaporated before crystallisation and, especially for an open pan technique, the additional fuel requirement may be excessive.

W.3.

The availability of machinery can affect the choice of technology. Although Indian manufacturers are increasing their production of equipment for small sugar factories, it is still easier to buy machinery for large-scale industry (Bhat & Duguid, 1980).

Economic

W.4.

When new areas are cultivated cane production and sugar recovery may be uncertain. It is then better to start a small sugar producing plant than to invest in a large factory because should the cane supply be less than expected the capital loss will not be so large. The small factory provides an opportunity for training management and labourers and for trying different varieties of cane while still producing a reasonable quality of sugar. On the basis of this experience the decision to start a large-scale factory can be made with more confidence. The small production unit should be so designed that it can either be expanded or transferred to another new production area (Tainsh, 1975).

Social

W.5.

It is often stated that mechanical harvesting is necessary to provide a regular supply of sugar cane to large processing plants. To avoid unemployment however, it may be desirable to cut and load the cane by hand. These operations can be made more efficient by providing better food, wages and tools for the labourers (UNIDO, 1977).

W.6.

A new factory will contribute less to the local community if its level of sophistication is far beyond that of local craftsman. The development of service functions is only possible when their capabilities match the technological requirements of the factory.

A UNIDO paper (UNIDO, 1980) at the 'Workshop on Appropriate Technology for the Production of Sugar' stated:

"The growth of the sugar industry makes integrated rural development possible, provided that the technology adopted is in harmony with the general level of technological development. To the degree that the technology chosen does not correspond to the development level of its environment, the industry parasitizes the rural economy. According to a recent study (Garg, 1980), in most developing countries up to 35 per cent of the equipment required for an OP plant - tanks, heating beds and furnaces - can be fabricated locally with local skills and materials. OP technology could be easily adapted to the level of technological development of developing countries. Indigenous engineering capabilities could be developed to service imported components, later to make replacement parts, and finally to make these components domestically. This would not, however, be possible at present in the case of large-scale VP technology which uses highly sophisticated, automated processes and equipment. Not only would the basic equipment and spare parts for large-scale VP-plants have to be imported but their high level of technological sophistication would also provide little or no opportunity to develop domestic engineering capabilities for some time to come".

Policy

W.7.

The interest and exchange rates control the prices of capital goods. In some countries capital goods are too cheap because of the low interest rate and favourable rate of exchange set by the government to stimulate industrialisation. In such a situation private entrepreneurs choose capital-intensive rather than labour-intensive technologies.

W.8.

Preferential taxation can favour certain production processes. OPS plants obtain a lower recovery of sugar from the cane and thus have higher raw material costs per tonne sugar than larger processing units. Because in India OPS plants are subject to only 50% of the taxation imposed on large scale producers, they are nevertheless profitable.

W.9.

The government may impose other regulations to control large processing plants. In India factories with multiple effect evaporation processes must keep a stock of sugar for market regulation and governmental distribution. For 60% of their produce the price is fixed below the free market price of sugar. VP plants must also cope with a fixed minimum price for cane and a numerically defined workforce monitored by the trade unions. It is therefore not surprising that OPS sugar tends to sell at prices 5-10% below the free market price of VP sugar.

Ecology energy

W.10.

The efficiency of cane utilisation can be important in cases where there is a limited area available for cane production. Total yields in kg product per 100 kg cane differ from 7-8 for Khandsari sugar to 11.2 for the modern large-scale produced crystal sugar.

W.11.

When production areas are scattered large-scale processes will need more fuel for the transport of raw material than small-scale processes. Processes without multiple effect evaporation however need much more energy and extra wood for fuelling Khandsari factories may not be available in some areas (RTI, 1977).

This list of remarks is far from complete, but it illustrates the kind of criteria that should play a role in decision-making. A criterion cannot be considered in isolation. Economic considerations for instance should never be the single reason for a certain choice.

11.9.3 Technology assessment and research

Having, on paper, chosen the most suitable technology, the decision must be confirmed by trials and pilot plant research. The success of measures proposed to overcome problems recognized in the initial survey and difficulties not foreseen at that stage will to a large extent determine the outcome of the project.

The economic disadvantages of small-scale technologies are likely to persist so long as research activity is concentrated on large operations. Given the same share of research and development support that large-scale sugar processing has received, there is no reason why the efficiency of smaller units should not be similarly increased.

The most important research areas are adapted from UNIDO, 1980:

(1) Improving the efficiency of OPS technology. In India for instance, research is taking place on the use of an expeller for cane crushing to increase sugar recovery. To improve the boiling process, a plate evaporator which reduces inversion by shortening the boiling time is under development (Bodewes, 1980). The recovery of sugar from molasses by ion exchange is also being studied (Reddy, 1978).

(2) The possibilities of scaling down multiple effect evaporators for small-scale processes should be studied.

(3) Not all developing countries have a surplus of labour. Small-scale processes should be made more suitable for situations characterised by high costs of labour per unit of employment.

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12 Cassava

12.1 CASSAVA CULTIVATION

Cassava (Manihot esculenta Crantz) originated in Latin America but is now distributed over a large area of the tropics. It is known under a variety of names (Grace, 1977): ketella, ubi kayu or kaspe in Indonesia, manioca or yucca in Spanish America, mandioca or aipim in Brazil, manioc in francophone Africa, tapioca in India and Malaysia, and cassava in anglophone Africa, Thailand and Sri Lanka.

The plant is a short lived shrub, 1-5 m in height, that produces lobed leaves on branched grey stalks, and forms a cluster of starchy tubers at the stem base. The tubers consist of a fibrous peel (10-15% of tuber weight) and a core which is the main storage region for starch.

The peel is difficult to rasp and has only about half the starch content of the core. It is therefore removed before processing, except in larger starch and animal feed industries. The tuber composition can vary as indicated in Table 13.

Cassava is a tropical crop that grows best in lowlands at around 26 ^{o}C, but may be grown at altitudes up to 2000 m and temperature ranging from 10-35 ^{o}C. As it can be cultivated on soils that are too poor to raise other crops economically, it is often grown as a food reserve on land not otherwise used for agriculture (i.e. steep slopes, forest fringes, or areas exhausted by other crops).

The cultivation of cassava is relatively easy and not labour-intensive. After planting the cassava field require little attention apart from the replacement of cuttings that have not developed and some weeding. Although cassava is subject to attack by various virus diseases and pests, it is a hardy crop that can survive periods of drought. Harvesting is usually done by hand. Mechanical harvesting is possible but expensive because of the amount of soil which must be displaced. The optimal time for harvesting may vary with circumstances and cultivar from 6 to 24 months after planting. Generally harvesting takes place after 1 year if the tubers are to be used as food and between 1 and 2 years if the crop is for industrial purposes (de Vries, 1978). Figure 21 shows the importance of choosing the optimum age for starch production.

The yield of cassava tubers varies between countries from 4 to 20 tonnes per hectare with a world average of 8.8 tonnes per hectare (FAO,

Table 13. Proximate composition of cassava roots. (from Edwards, 1974)

Water	65 - 70%	Protein	1 - 2%
Starch	20 - 30%	Fibre	1 - 2%
Sugars and fats	5%	Ash	0.5 - 1%

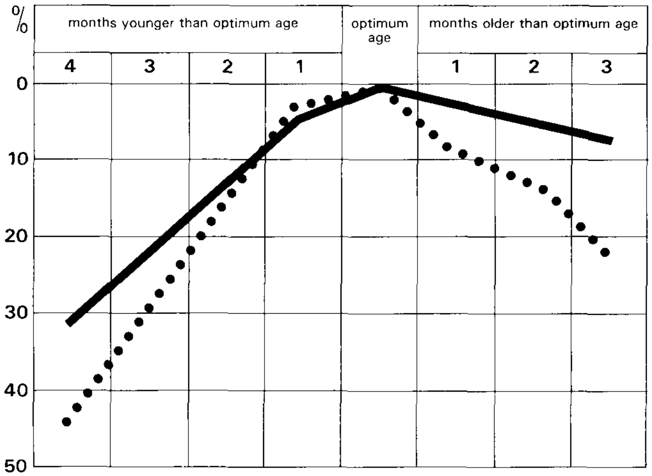

Fig. 21. Percentage (w/w) loss in yield of whole tubers and starch, relative to yield at optimum age. The solid line refers to whole tubers, the dotted line to starch. (from Holleman & Aten, 1956)

1981). Yields depend on conditions, cultivars, use of fertilizers and land preparation.

An important factor in the production and use of cassava is the very limited keepability of the tubers after harvest. Experiments have shown that cassava can be stored for limited periods in earth covered clamps or by freezing or wax-fungicide coating. However these methods are either impractical or too costly for economic application on a large scale. Cassava tubers therefore need to be processed or consumed within 24 to 48 hours after uprooting. For this reason harvesting is often delayed although this reduces product quality and occupies land unproductively.

12.2 USES

Cassava is mainly cultivated for its tubers, but all parts of the plant can be utilised. In many countries cassava leaves are used as a vegetable and are as such an important source of vegetable protein. Cassava is also cultivated for animal fodder. Table 14 gives an overview of the major uses of the cassava plant. The most important food and non-food cassava products for local and world markets are listed in Table 15. Of these categories food production for the local market and non-food production for the world market are of major importance. The other two categories represent only small quantities of cassava.

12.2.1 Cassava as food

It is estimated that cassava is a staple food for at least 200 million people (Coursey & Haynes, 1970) and possibly for as many as 420 milion (Philips, 1974). Cassava makes important direct and indirect contributions to the world food supply in three ways:

Table 14. Major uses of the cassava plant.

- CASSAVA PLANT
  - Leaves
    - Cooked vegetable
      - soup ingredient
      - supplement for fortified foods
      - protein concentrate for human consumption
    - Animal feed
      - silage
      - dried for feed supplementation
      - leaf meal for feed concentrates
  - Stalks
    - Horticultural uses
      - cuttings for propagation
      - grafting stock
      - mulch for soil improvement and to prevent erosion
    - *Animal feed*
      - mixed with leaves as ruminant feed
      - dried for feed concentrates
  - Tubers
    - Used directly as human food
      - raw, peeled young root (aipim)
      - boiled, baked roasted
      - fried slices or chips
      - shredded and mixed with other ingredients
      - juice for drinks and sauces (tupucy, cassaripo)
    - Used after size-reduction, fermentation and drying → Fermented flour
      - Farinha d'agua, Farinha secca
      - Gari, Eba, Foufou, Atjéké
      - Porridge or gruel
      - Cassava cakes (Beiju, Casabi, etc.)
      - Raw material for fermented drinks
    - Used after chipping and drying
      - chips (kokonte, gaplek, raspa)
        - Non fermented flour
          - Cassava cakes (chapatis)
          - Porridge, pastes, doughs
          - Thickener in soups and gravies
          - Composite flour ingredients in bakery products and pasta products
          - Glues and adhesives
        - Used as human food after rehydration
        - Animal feed/pellets
        - Extracted for starch
    - Extracted for starch
      - starch (also from chips "Extracted for starch")
        - Tapioca (gelatinized starch pearls, flakes, etc.)
        - Cassava cakes
        - Bakery products (pure of composite flours)
        - Pasta products (Mie, etc.)
        - Fish or shrimp crackers (Krupuk)
        - Puddings, pie fillings (sago)
        - Infant foods
        - Dusting or moulding agent in confectionery
        - Thickerners in soups, jellies, etc.
        - Malt adjuncts in beer brewing
        - Pharmaceutical starch
        - Textile sizing and strengthening
        - Laundry starch
        - Paper sizing and bonding
        - Gums, adhesives, glues
        - Raw material for alcohol, acetone, glucose dextrins and modified starches
        - Oil well drilling
    - Tuber residues used as animal feed
      - root peel
      - broken roots
      - fibre and bagasse from starch extraction (also used as fuel)
      - wet pulp (also used as fertiliser and mulch)

Table 15. Important food and non-food cassava products for local and world market.

	Local market	World market
Food	farinha	tapioca
	gari	thickeners
	gaplek	starch
	tapioca	modified starch
Non-food	animal feed	textile starch
	glue	animal feed
	alcohol	chips and pellets

- consumption (after household processing) as primary, secondary or supplementary food;
- utilisation of roots and other parts as animal feed and subsequent consumption of the animals by man;
- utilisation of flour or starch, derived from industrial processing, in manufactured foods for human consumption.

Of these the consumption as primary, secondary or supplementary food is by far the most important requiring 70-90% of the total world production. The role of cassava as a food crop however differs in the individual producing countries. In Brazil cassava is a main staple especially in rural areas, while in the important producing country Thailand it is predominantly a cash crop or normally used as a staple food. Indeed in most of South East Asia cassava has the image of being a poor man's food and mainly exported for animal feed and other non-food purposes. In South America and Africa it is predominantly used for direct human consumption, with the exception of the increasing cultivation of cassava in Brazil for fuel alcohol production. In Table 16 the differences in the utilisation patterns of cassava in some major producing countries is given.

12.2.2 Nutritional value

The nutritional composition of cassava is presented in Table 17. Although nutritionist consider cassava an 'inferior' crop because of its low protein content it has advantages for the producer and consumer:
- A high food energy yield. Cassava produces more kilojoules per unit time per unit area than most other staples (Table 18).
- A high biological efficiency in the production of edible matter. In cereals a large part of the energy from photosynthesis is needed for building stalks to support the grains, whereas in root and tuber crops such as cassava there is no such requirement. Only 36-50% of the total plant mass of cereals is edible while 63-85% of root and tuber crops can be consumed by humans.

Cassava is principally an energy provider and in many production areas it is considered a typical reserve food crop. The energy density of starch products (in kJ/volume unit prepared food) is much lower than that of fats or sugars. Relying on cassava or starch as the only source of food, energy will lead to problems because not enough food can be consumed to supply the necessary energy ('rice or cassava tummy').

12.2.3 Toxicity

Cassava for food use must be processed to remove potentially toxic cyanide-containing substances. Remarkably little quantitative information

Table 16. Cassava production (FAO Yearbook, 1975) and utilisation in 1975 in some major producing countries. + = positive, - = negative or only small amounts, values in estimated percentage of total production. (from Booth & Wholey, 1978)

	Nigeria	Indonesia	Thailand	W.Malaysia	Philippines	Brazil
Production						
Area (ha x 10^6)	1.10	1.50	0.43	0.01	0.09	2.03
Yield (t/ha)	6.6	8.6	14.8	21.6	5.4	14.6
Production (t x 10^6)	7.3	12.92	6.36	0.26	0.48	29.5
Utilisation (% w/w)						
Human food (%)	95	90 (Human food and Starch internal/export combined)	-	+	67[1]	+
Starch internal/export	-		+	+	27	+
Animal feed internal	-	-	-	+		+
Animal feed export	-	+	++	-	6	+

1. Castillo (1974).

Table 17. Composition of some cassava products in comparison to other staple foods (Platt, 1962) and the estimated daily requirements of adult males (FAO, 1974).

	Composition per 100 g edible portion					Adult male daily requirement per day
	Fresh cassava tubers	Cassava flour	Rice (milled and polished	Maize meal (95% extr)	Potato	
Water (g)	60	12	12	12	80	
Energy (kJ)	658	1470	1522	1557	322	12900
Protein (g)	0.7	1.5	7.0	9.5	2.0	37
Fat (g)	0.2	-	0.5	4.0	-	
Carbohydrate (g)	37	84	80	72	17	
Fibre (g)	1.0	1.5	0.2	1.5	0.4	
Calcium (mg)	8	55	5	12	10	400-500
Iron (mg)	1.0	2.0	1.0	2.5	0.7	5-9
Vitamin A (I.U.)	-	-	-	-	-	7500
Thiamin (Vit. B_1) (mg)	0.07	0.04	0.06	0.30	0.1	1.2
Riboflavin (Vit. B_2) (mg)	0.03	0.04	0.03	0.13	0.03	1.8
Nicotinamide (mg)	0.7	0.8	1.0	1.5	1.5	19.8
Ascorbic acid (Vit. C) (mg)	30	-	-	-	15	30

Table 18. Energy productivity of some important staple foods. Yields for cereals exclude non-edible parts of the plant. (from de Vries et al., 1967)

	Crop yield (t/ha)	Energy content (kJ/kg x 10^3)	Edible portion (%, w/w)	Energy yield (kJ/ha x 10^6)	Period of vegetation (days)	Energy yield per day (kJ/ha per day x 10^3)
Rice	2.0	15.1	70	21.5	150	142
Wheat	1.2	14.8	100	17.6	120	146
Maize	2.1	15.6	100	32.7	135	241
Sorghum	1.0	15.3	90	13.8	135	103
Cassava	9.1	6.6	83	49.9	330	151
Sweet potato	6.5	4.9	88	28.0	135	206
Yam	8.0	4.5	85	30.5	280	108
Colocasia	5.8	4.9	85	23.7	120	198
Banana	21.1	5.5	59	68.4	365	189

about the effects of processing on toxicity and its significance for humans is available. There is a great variation in toxicity between different cultivars. A distinction is usually made between 'sweet' and 'bitter' cultivars. The 'sweet' cultivars were considered non-toxic while the 'bitter' ones were considered toxic. Although the 'sweet' cultivars generally are less toxic there is no direct correlation between toxicity and taste (Coursey, 1973). Cyanide levels from 6-370 mg/kg have been found depending on cultivars growing conditions (i.e. soil type, humidity, temperature) and the age of the plant. The cyanides are found in two different forms:

- 'bound' cyanide (glucosides: linamarine and lotaustraline)
- 'free' cyanide (non-glucosides: HCN and cyanohydrine)

Free cyanide comprises 8-12% of the total tuber cyanide. The lethal dose of free HCN for an adult is 50-60 mg but the toxicity of bound cyanide is less clearly understood. The glucosides are broken down in the human digestive tract resulting in the release of HCN. All traditional cassava processing methods reduce or remove the toxicity by releasing HCN from the glucosides. HCN is soluble in water and has a boiling point of 25 ^{o}C. It can thus be removed by soaking, boiling, baking or drying. Boiling the fresh cassava has little effect on its toxicity as the glucoside linamarine is heat resistant and the enzyme linamarase is inactivated at 75 ^{o}C. Most processes rely on enzymic hydrolysis to reduce the glucoside concentration. In practice, the extent of glucoside breakdown is mainly controlled by fermentation time. Peeling also reduces the toxicity as the concentration of cyanides in the peel is 3-15 times that in the core. Unfortunately, there is little reliable quantitative information on the reduction of toxicity after processing. Even if the cyanide content is reduced by processing, intoxication may still occur if cassava is consumed in large quantities. Many millions of people, however, regularly consume cassava products without apparent harm although the processing is primitive. Traditional processing methods should only be changed when it can be shown that the new product is as safe as the old.

12.3 WORLD MARKET

After utilization for human food, the second most important use of cassava is as an export crop in the world market. This market is dominated by the importing countries. The main cassava products of international trade are:

- chips and pellets used mainly in the animal feed industry in EEC countries
- starch used mainly for industrial purposes in the USA, Canada and Japan

The export of cassava products is limited by the availability of the raw material and by the demand for cassava products, usually of a specified quality. The potential supply of cassava for export is the difference between production and local demand for human consumption. Before 1970 increases were mainly due to an increase in planted area, but after 1970 yields per hectare also rose. Local consumption is rising because of rapidly increasing populations and new demand for cassava for animal feed, industrial uses and fuel (e.g. in Brazil alcohol is produced from cassava). So far most producing countries can still export cassava after local demand has been satisfied. This is indicated in Table 19 where productions and (projected) demands are shown.

EEC countries import 2.0-3.5 million tonnes of cassava chips and pellets per year for animal feed. This represents 20% of the total demand for cassava and 80-90% of the exported tonnage (Phillips, 1974b). The most important exporting countries are Thailand and Indonesia. Cassava products for animal feed have reached their important position in the EEC because of their favourable price in comparison to grain. The market in raw materials for

Table 19. Production of cassava in tonnes x 10^3 and 1980 demand as projected by Phillips (1974a). (from FAO, 1981)

	Production		Projected demand		Production		Projected demand
	1969-1971	1980	1980		1969-1971	1980	1980
Argentina	296	200	118	Gabon	155	113	191
Bolivia	223	224	163	Ghana	1533	2250	1693
Brazil	29922	24554	7436	Guinea	467	500	450
Colombia	1380	2640	748	Ivory Coast	546	750	347
Ecuador	382	185	124	Kenya	510	635	585
Paraguay	1442	1950	552	Liberia	264	310	282
Peru	477	410	561	Madagascar	1227	1450	663
Venezuela	317	382	395	Mali	36	56	73
				Mozambique	2549	2800	-
India	4993	6500	3922	Niger	182	225	128
Indonesia	10695	13300	14708	Nigeria	9473	11000	9374
Sri Lanka	376	530	396	Rwanda	333	469	80
Thailand	3208	13500	872	Senegal	159	114	203
Vietnam	950	4000	315	Sierra Leone	75	95	85
Malaysia	271	410	102	Sudan	133	122	2760
Philippines	436	1900	824	Tanzania	3373	4600	1541
				Togo	562	450	596
Angola	1597	1850	1399	Uganda	1058	1300	1103
Benin	533	720	530	Zaire	10232	12500	10480
Burundi	843	1200	52	Zambia	159	177	203
Cameroon	637	1000	742				
Centr.Afr.Rep.	767	980	680	Latin America	35224	31579	10838
Chad	140	181	54	Far East	20031	36236	21318
Congo	543	543	515	Africa	38273	46651	35444
				World	96760	122134	71500

animal feed is highly variable and depends on EEC policy on feedstuffs. Cassava can be replaced by other products if prices change. EEC regulations allow maximum cassava contents of 0-20% (w/w) in animal feeds depending on the type of feed.

As badly processed pellets cause serious problems in bulk handling (dust pollution and losses), and the adulteration of cassava products has often been detected, the EEC has therefore formulated strict specifications (Source: Ingram, 1975)

Starch, min.	62% (EEC method)
Raw cellulose, max.	5%
Sand, max.	3%
Moisture, max.	14.0% (October-May)
	14.3% (June-September)

The demand for cassava starch, mainly from the USA, Canada and Japan, amounts to 100 000 - 400 000 tonnes per year (Phillips, 1974). Cassava starch represents only about 10% of the total starch market. The large variation in demand and the small market share are most likely due to the following factors:

(1) The developing countries are usually unable to produce starch of adequate quality. The necessary quality can only be readily obtained from modern large-scale processing equipment. In most developing countries starch processing is still a simple de-centralised industry. The establishment of "starch refining" plants, processing locally produced basic starch for export, could overcome this problem.

(2) The functional properties of cassava starch can be obtained, if necessary, by modification of corn and potato starch. It thus shares the market with these starches which are produced in vast amounts in the industrialised nations.

(3) Cassava starch is generally not competitive in price. Although labour costs at the point of manufacture are low, the economies of a large-scale operation are seldom fully realised. The cost of transporting the starch to the importing country must also be recovered.

(4) The important markets for cassava starch are either protected or monopolised by large companies. In Japan, imports are regulated by quota. In the USA and Canada the maize starch companies monopolise the starch market.

The most serious of these factors are the high quality requirements and the ease of substitution (Table 20).

12.4 RAW MATERIAL SUPPLY AND MARKET

The information compiled in the preceeding sections outlines the boundary conditions of raw material supply and market possibilities for cassava. This information is neither complete nor very detailed and may have to be extended for specific cases. It is however essential for making a choice between alternative uses of cassava and subsequently evaluating available technologies on the 'must criteria' raw material supply and marketing possibilities.

The status of cassava as a food reserve can lead to competitive situations in agricultural production and conflicts of interest between producers, processors and consumers.

Firstly the farmer must divide the available land between cassava and other food crops. Secondly he will have to decide which part of the cassava

Table 20. Quality requirements for cassava starch set by various importing and exporting countries. (from Ingram, 1975)

	India		Brazil	Malaysia		USA		UK	Sri Lanka
	edible	textiles		edible (Grade A)	industrial	paper	food		paper
Starch % min. (dry basis)	98.0	98	80	-	-	-	-	-	-
Moisture % max.	12.5	15.0	14	12.5	12.5	13.5	14.0	8.12	15.0
Ash % max. (dry basis)	0.5	0.4	1.0	0.4	0.5	0.2	0.3	-	4.0
Fibre % max. (dry basis)	0.3	0.6	-	0.2	0.8	-	-	-	-
pH of slurry	4.5-7.0	>4.8	-	3.8	3.8	6.5-7.0	5.0-7.0	-	5-8.5

produced will be reserved for food and which part will be sold as a cash crop. The outcome of these decisions is influenced by the advantages of cassava previously mentioned and summarized below:

- Non seasonal crop
- High food energy productivity
- Low production cost
- Relatively little affected by pests and diseases
- Easy storage when left in the ground
- Easy preparation

Generally, however, cassava has the image of being a poor man's food. The success or failure of other crops will, to a large extent, control the availability of cassava for industrial processing. In periods of drought, or when a food shortage is imminent, cassava will be withheld for direct consumption unless the processor manufactures a locally recognised foodstuff from it.

A third competitive situation may arise when different products require cassava from the same source. Gari production for instance can compete with starch manufacture. Particularly for large scale industries, which are usually capital intensive, a regular supply of cassava is of vital importance as the roots cannot be stored in the fresh harvested form. Irregular supply may lead to underutilisation of the capacity. A regular supply of raw material for large-scale processing can only be obtained by measures such as contract farming or the establishment of a factory plantation. An appropriate policy can ensure that farmers grow cassava for external processing.

In the local market cassava thus competes with other staple foods, while commercial cassava products compete with products prepared and consumed in the household. The balance of these factors helps to determine the availability of raw materials for export oriented production.

In the export markets, cassava products (chips, pellets and starch) compete with other materials that can replace them. Quality and competitive pricing therefore determine the volume of cassava which can be exported.

12.5 AVAILABLE TECHNOLOGIES AND THEIR EVALUATION

In Table 14 a large number of processed cassava products are listed. Most of the processing for these products is done at household or village level with traditional methods only. Sometimes small improvements in technique or equipment have been made. An overview of traditional household cassava processing was published by Gietema (1970) in Dutch. For some products, there have been attempts to transform these processes into small-scale localised industrial operations. This has led to 'post-traditional' or 'intermediate' level processes.

To illustrate the approach to technology selection, three products sold in different markets have been chosen:

- Cassava starch: a product for export and industrial use which in some countries is also an ingredient in local food products
- Chips and pellets: products for animal feed and export
- Gari: a local fermented food

These products have in common that they can be produced in traditional and intermediate industries as well as in modern large scale industries.

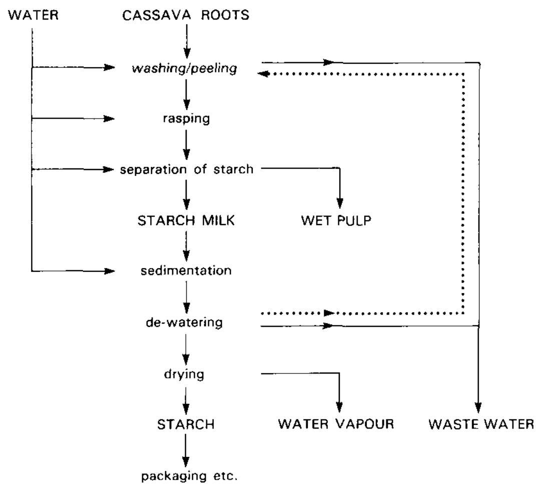

Fig. 22. Basic flow sheet for cassava starch production.

12.5.1 Cassava starch

12.5.1.1 *Basic process*

Cassava starch can be quite easily released and separated from the tubers because they contain relatively minor amounts of other components (see Table 13). As is shown in the flowsheet (Figure 22), the production of starch takes place in six stages. Depending on the scale and technology chosen, 6-12 different unit operations are incorporated in the process.

Effective washing and peeling lays the basis for good starch quality by removing dirt, the coloured corky outer skin and sometimes also the fibrous cortex. Removal of the cortex (about 20% (w/w) of the tuber weight) is necessary in small-scale operations where low-powered rasping equipment is used. Washing may be done by hand and with simple paddle washers, or in larger scale operations by water jets. Mechanical peeling by abrasion, brushes, paddles, or some combination of these, is used but it does not completely remove the cortex. Handpeeling is more effective.

The final recovery of starch depends largely on the fraction of cells that have been ruptured during rasping to allow the release of starch granules at later processing stages (i.e. the rasping efficiency). Rasping equipment ranges from locally constructed roll or disc rasps (maximum capacity 1000 kg per day) to sophisticated cylindrical rotating drum rasps fitted with exchangeable blades. Hammermills are also used. Small rasping equipment may be driven by foot, waterwheel or small combustion engines. Larger machines run on electricity.

Separation of starch from the pulp and fibres consists of two processes:
- Washing starch out of the ruptured cells with water.
- Separation of the starch suspension (starch milk) from the remaining pulp and fibre.

These processes may be done separately, or together as in "wet screening". The simplest method is wet screening by hand on a woven cloth. Mechanised wet screening equipment ranges from locally made rotating drum screens and shaking flat-bed screens, to multi-stage DSM-screens (sieve-bends) on which the pulp is washed in 3 or 4 counter-current stages. Centrifugal sieves (centrisieves), in which the pulp is washed 2 to 5 times on fast rotating conical screens in a countercurrent system, are also used in large-scale operations.

Sedimentation and de-watering are purification processes in which the starch milk is washed with clean water before mechanical removal of as much water as possible prior to drying. The aqueous extract, the fruit water, contains soluble materials such as sugars, proteins, salts and amino acids. To prevent chemical- and enzymic reactions and the development of micro-organisms, all operations on the wet starch should be completed without delay. During starch extraction and sedimentation, chemicals may be added to accelerate the process and improve starch quality. Sulphuric acid, sulphur dioxide (0.3-0.4 g/l starch milk), aluminium sulphate (21 g/l) and chlorine (1 ml/l) can all be used to lower viscosity and whiten the final starch.

Gravity sedimentation is the simplest method. Water is added to the starch slurry in large wooden or concrete tanks (approximately 2 m x 2 m, depth 0.5-1 m) and over a period of about six hours the starch accumulates at the base of the tank. The fruit water, which is removed by decanting, may contain 5-10% of the total starch. Improved gravity sedimentation is obtained on "settling tables" (length 50-100 m, width 1.5-2 m, depth 0.3-0.4 m). Starch milk is fed in at one end of the channel and as it slowly flows to the other, starch settles out. The advantages of the settling table over tanks, are a shorter contact time of starch and fruit water, lower starch losses in decanting and less labour required for unloading. Settling tables may have capacities up to 2-3 tonnes of dry starch per table per day. Settling and de-watering takes about 6-8 hours per batch. The final moisture content of the starch is then 450-500 g water/kg wet starch.

Centrifugal separation can increase capacity and further reduce processing time. Centrifugation may be a batch or a continuous operation. Various types of continuous centrifuge including decanters and nozzle centrifuges are used. Starch separation can also be achieved by hydrocyclones with countercurrent washing. In large factories special de-watering centrifuges or rotating vacuum filters are used for de-watering to about 400 g water/kg wet starch.

After sedimentation the de-watered starch has to be dried to obtain stable transportable native starch. Drying can be done in three ways:

(1) The cheapest and simplest technique is sun-drying on bamboo mats or on flat baskets. This is employed in rural operations for capacities up to 3-5 tonnes of dry starch per day. Internal transport and space requirements are the size-limiting factors. Drying times depend on weather conditions (in dry sunny weather, about 8 h).

(2) Drying in hot air is common in slightly larger operations. Various types of hot air driers with drying times of minutes or hours are used. Oven or chamber driers, revolving drum driers, belt- and tunnel driers and batch fluid-bed driers all find application. Large plants now commonly use pneumatic 'flash' driers in which the wet starch is dried in seconds during transport in very hot air (about 200 ^{o}C).

(3) Contact drying wet starch on a hot surface is done in plate ovens and with roller driers. Gelatinization (cooking) of starch is a risk with these methods because of the high temperatures involved.

Drying should reduce the moisture content to 100-130 g water/kg product. Lower moisture contents may damage the starch and reduce its re-moistening capacity, while higher moisture contents increase the risk of spoilage by moulds. Tapioca pearls and flakes are made by a combination of drying, partial gelatinization and shaping in the drying stage. After drying, the crude dry starch may be ground in hammermills and sieved (bolted) before packaging.

Process water is used in large quantities. Water requirements range from a few cubic metres per day for very small operations to about 50 m^3 per hour for large plants (2-12 m^3 water per tonne of roots processed). To reduce water consumption, counter-flow processing or re-utilisation of water may be employed (the dotted line in Figure 22). As starch is in close contact with water during most of the process the quality of the water is important. It should have low concentrations of suspended and dissolved solids. Soluble iron salts can cause a serious loss of product quality because of the formation of strongly coloured complexes with HCN. The amount of waste water produced may exceed the quantity which the environment can accept without adverse results. Large starch refineries in particular will have to treat their waste before discharging it. The cyanide in the waste water may poison microbiological treatment plants.

Fibrous pulp is the principal by-product of starch refining. The main use of the pulp, either wet or dry, is in animal feeds, as a fertilizer or for mulching. Because of its high water content and colloidal nature, the pulp requires a high energy input and much handling during drying. A more valuable use of the wet pulp is as a raw material for the production of citric acid and other chemicals by fermentation.

More detailed information about cassava starch processing, equipment and starch quality is given by Grace (1977), Holleman & Aten (1956) and Ingram (1972,1975). Information about large scale processes can be obtained from equipment manufacturers and engineering consultants, for example: Dorr Oliver, Alfa Laval, Westfalia, Nivoba (Holland) and Starcosa.

In the following sections an outline of the production of cassava starch at three different scales and levels of technology is given:
- small village level operations producing about 250 kg of starch per day;
- intermediate or 'post traditional' operations producing about 1-5 tonnes per day;
- modern large-scale operations producing about 10-25 tonnes per day.

The data are derived from Würdemann et al. (1979), Edwards (1974) and other sources. The situations described are typical for South East Asia, but the information can be made applicable to other parts of the world by adaptation of the figures.

12.5.1.2 *Small scale processing*

Small-scale rural operations are located close to cassava growing areas and a good supply of water (e.g. a stream). They are usually close to roads suitable for lorries. The typical factory consists of an open-sided shed in which wet processing takes place and is surrounded by an area (200-300 m^3) for sun-drying. Processing follows the flowsheet in Figure 23.

The cassava roots are usually peeled on the farm and carried to the factory by the farmers. After weighing they are washed by hand and by trampling in water, and then pulped on a simple roll or disc rasp. The rasp is driven by a small combustion engine (4-8 KW) or a water-wheel. The starch is then washed out of the pulp by hand on nylon screens (4000 m^{-1} or 100 mesh). As the efficiency of the rasp is about 80%, 20% of the available starch remains in the pulp after washing. The starch milk then flows into simple settling tanks. After settling, the water is decanted and the wet starch cake is crumbled by hand through screens. The starch is then sun-dried on flat baskets to about 130-150 g water/kg product and packed in jute bags. The overall recovery of available starch in this type of process de-

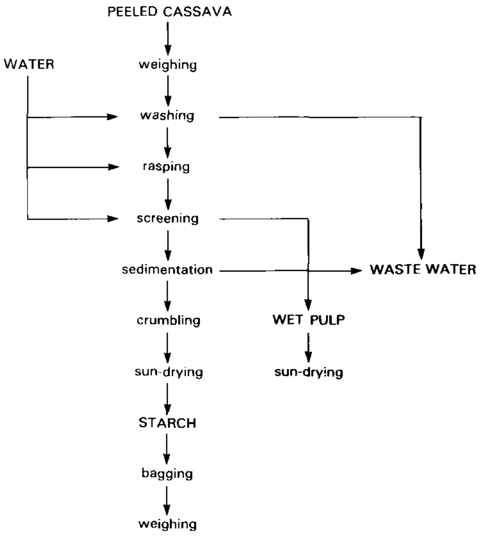

Fig. 23. Flow sheet for small scale cassava starch production.

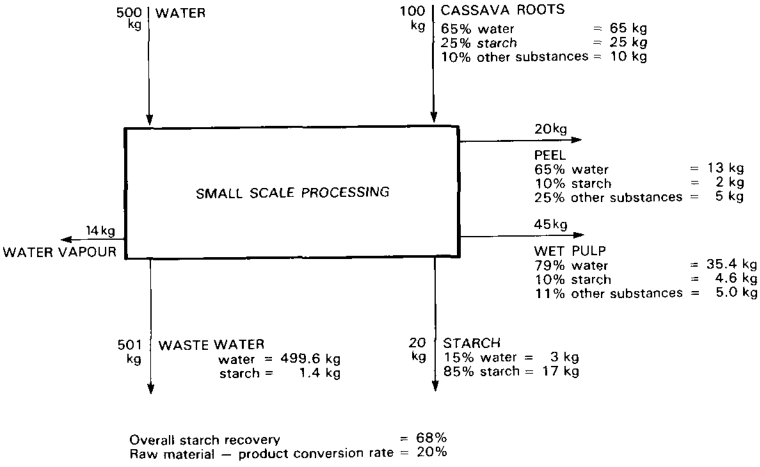

Fig. 24. Estimated mass balance for small scale cassava starch production. Water requirements and by-product quantities based on 100 kg cassava roots.

pends on the care taken by the processor and varies from 50% to 70% (w/w). In Figure 24 an estimated mass balance for the process is given.

The important characteristics of operation are low capital investment and seasonal character. In many places the factory operates only in the dry season when sufficient sunlight is available for drying (approx. 150-170 days per year). As there is no return on investment during the wet season and the owner usually operates with borrowed capital, he restricts his financial outlay.

The raw material is produced by small-holders and bought at the factory gate. An adequate supply can be easily arranged by personal contact. The factory is usually operated by the owner and his family or relatives (3-5 persons).

The quality of starch produced depends on various factors, the most important of which is the quality of water available. Weather conditions can also affect the starch quality. During rainy periods the cassava tubers arrive at the factory in a dirty condition. The drying period may also be extended from 1 to 4 days leading to microbial deterioration. Despite the very simple equipment used, these village operations often produce starch of remarkably high quality. This must be the result of a good water supply and personal attention at all stages of processing. The starch is usually sold by middle men who may sift and blend it. In South East Asian countries much of the starch is sold for local food use in products such as noodles and krupuk (fish crackers).

12.5.1.3 *Intermediate scale processing*

Intermediate scale factories (1-5 tonnes dry starch per day) are also located in villages with good water supply but access to main roads is essential for these plants. The factory consists of a simple building with about 400 m^2 floor space and a surrounding drying area of 0.5-2 hectares.

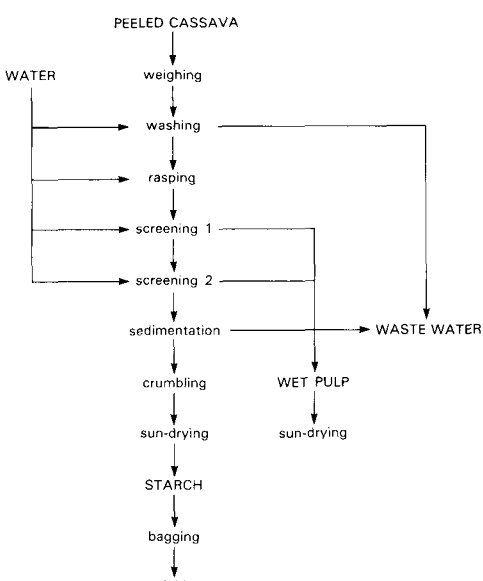

Fig. 25. Flow sheet for intermediate scale cassava starch production.

Figure 25 is a flowsheet for the starch extraction process.

The roots are peeled on the farm. Washing is performed by hand, or with simple paddle washers. In South East Asia the rasper, usually locally built, is a relatively powerful roll unit with exchangeable blades. Water is added during operation. The washing out and separation of starch milk from the pulp usually takes place in a two stage wet screening process using shaking flat-bed screens and/or revolving drum screens (3100-4700 m^{-1} or mesh 80-120). The pulp is discarded into a pit and sold wet or in small sun-dried lumps. The powered equipment (paddle washer, rasper, shaking or rotating screen) is usually driven from a central diesel engine (20-45 KW or 30-60 HP) by belt and pulley systems. Settling tables are used for sedimentation. Chemicals are not usually added. The starch is left to de-water overnight and the wet cake (450-500 g water/kg product) is scrumbled and dried. Drying is mostly done in the sun but locally made hot air driers are also in use. Depending on the weather conditions, drying may require 6 hours to 3 days. The product is bagged at a moisture content of about 130 g water/kg product.

Starch recovery is similar to that in small-scale processes. Although rasping is usually more efficient, mechanical washing out is less effective than careful hand washing. An estimated mass balance is given in Figure 26. Intermediate scale processing differs from the small-scale one by the mechanisation of screening and washing. These operations are unpleasant and time consuming when manually performed. The introduction of more sophisticated separation equipment and centrifugal sedimentation to further improve the yield and quality of starch can only be justified by a much higher output. Sun-drying would no longer be feasible. Indeed in many existing plants of this type sun-drying is the capacity limiting factor, particularly in the rainy season (Würdemann et al., 1979). In contrast to small-scale factories, these operations are continuous industrial enterprises. The labour force of a typical factory would consist of:

- a manager;
- a foreman;

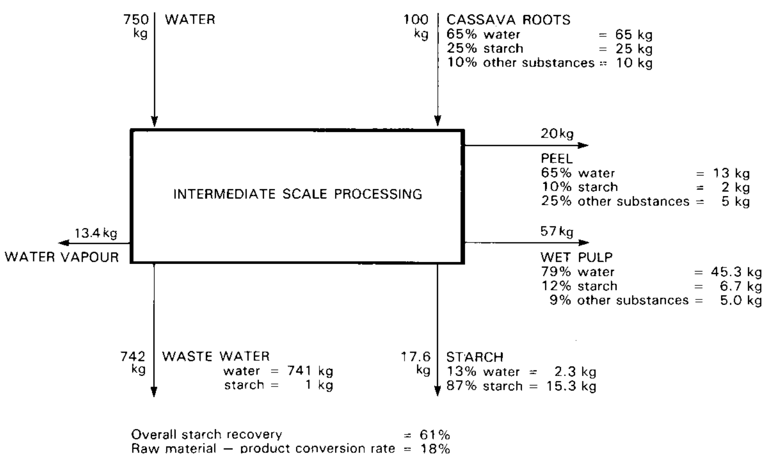

Fig. 26. Estimated mass balance for intermediate scale cassava starch production. Water requirements and by-product quantities based on 100 kg cassava roots.

- a mechanic;
- 5-10 full time workers engaged in wet processing;
- 20-50 daily paid workers engaged in drying and bagging.

Raw material supply is usually organised by the factory through travelling buyers who collect peeled roots from small-holders. The quality of the starch is similar to that made in the small-scale operations. Water supply and drying time again have a major influence on the quality of the starch. Intermediate scale factories produce more waste water than small-scale operation because of their higher capacity and the use of mechanical screens and settling tables which require a supply of water (see Figures 24 and 26). The by-products of starch manufacture pose a problem at this scale of operation. The treatment of large quantities of effluent requires a high investment and it may be difficult to economically dispose of the wet pulp at a rate equal to its production. Middle men are responsible for selling the end-product.

12.5.1.4 *Large-scale processing*

There is a large selection of processes and equipment for large-scale operations (minimum 10 tonnes of dry starch per day). The basic differences between these and smaller scale operations are in peeling, the use of multi-stage countercurrent starch extraction and refining, and hot air drying (Figure 27).

Because more powerful rasping machines are used, complete removal of the cortex is not necessary. After separation of the starch milk, extra processing steps improve the quality of the starch by washing out soluble substances, pulp, fibre particles and sand. The combination of sophisticated equipment and multi-stage counter-flow processing for both extraction and refining stages leads to higher overall recovery of available starch (75-93%), lower water consumption and higher starch quality. At this scale with its correspondingly high investment, irregular capacity utilisation

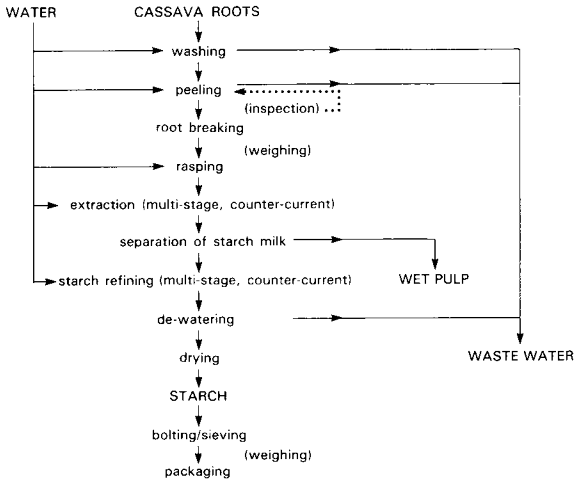

Fig. 27. Flow sheet for large scale cassava starch production.

caused by dependence on weather conditions has to be avoided and hot air drying is therefore essential.

The mass balances for the two large-scale processes shown in Figures 28 and 29 were provided by equipment manufacturers. The Alfa Laval process utilises centrifugal separators, while the Dorr Oliver process uses DSM-sieve bends and hydrocyclones.

An operation of this scale would be located in a rural area with access

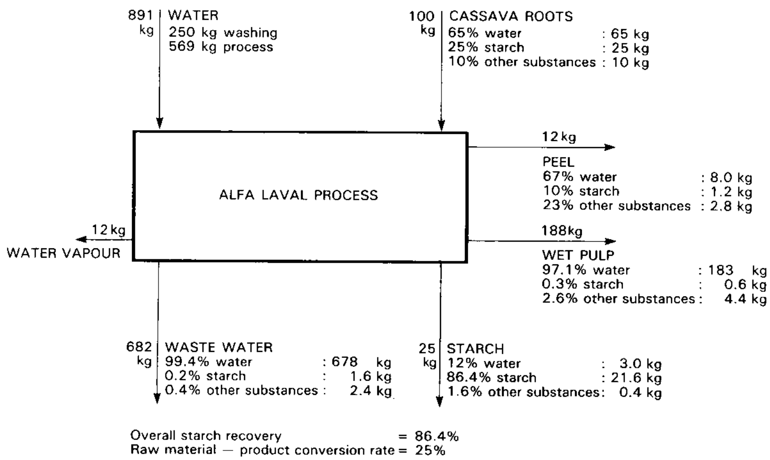

Fig. 28. Mass balance Alfa Laval process.

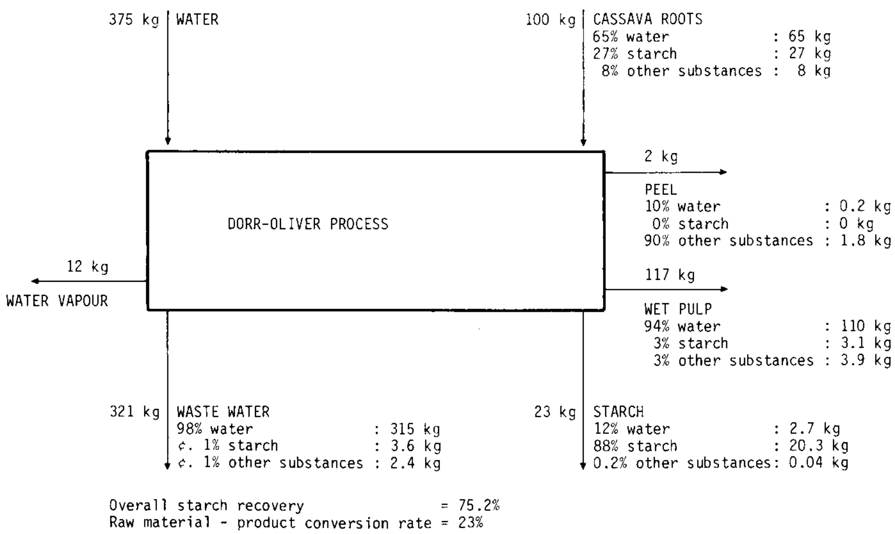

Fig. 29. Mass balance Dorr-Oliver process.

to an ample supply of water and facilities for the disposal of treated waste water. Good road connections with the cassava producing areas or its own plantation must be maintained all year round. The site occupies about 1.5 hectares and the factory has a floor area of about 3000 m^2 including storage space.

To ensure the steady supply of cassava tubers necessary for optimal capacity utilisation (a total of 10 000 - 25 000 tonnes per year) a factory plantation is usually established to provide a large proportion of the raw materials (50% or more). The rest is produced by small-holders under contract or bought by factory agents.

Waste water treatment and pulp disposal also require special attention. The simplest form of effluent treatment is a natural oxidation pond but often more elaborate treatment may be necessary. On site generation of steam and stand-by electricity is necessary to ensure continuous production in rural areas. The total workforce of the factory excluding the plantation is 50-60 perons (Grace, 1977). Of these at least two-thirds are skilled labourers or specialised qualified staff (mechanics, management, etc.).

The products for export are usually marketed directly by the factory organisation. In countries with a long tradition of exporting a government organisation is often involved in testing product quality and, on the basis of the results, issuing export certificates. Quality control during starch extraction and subsequent processing operations is necessary to maintain the uniform product quality demanded by the international market. The quality requirements for the local market are usually less strict. Distributors or middle men are likely to service the diffuse local market.

12.5.2 Chips and pellets

An alternative use of cassava is the manufacture of chips and pellets to be used in animal feed mixtures. In Thailand, Malaysia and Indonesia the production of these commodities is oriented towards export to the EEC. In many developing countries local demand for chips and pellets is now increasing. The production of chips and pellets may thus compete with the use of cassava for food. If the major aim of a project is to provide employment or to utilize excess cassava, animal feed production can also be an attractive option.

The flowsheet (Figure 30) shows that chip manufacture is an intermediate stage in the production of pellets. There is not a great difference in the technologies used at different scales of chip and pellet production. The main difference is in sun drying and mechanical drying. Chips can be produced by very simple techniques in the household or village as well as on larger mechanised scale.

In most producing countries cassava chips are made by farmers or specialised small-scale 'chippers'. The 'chippers' buy fresh tubers at the local market or obtain them directly from the farmer, in some cases harvesting the roots themselves. Pelletization of the chips is essentially a large-scale operation requiring suitable machinery. The factory obtains the chips either directly from individual producers or from middle men. Chips for the largest pelletizing plants may be manufactured on site to maintain the supply under adverse conditions.

Chips can be sold directly for animal feed, but because of their higher bulk density, pellets are preferred for export. Their volume is 25-40% less than the corresponding weight of chips so that transportation is cheaper. The savings in transport costs must be offset against the costs of pelletization.

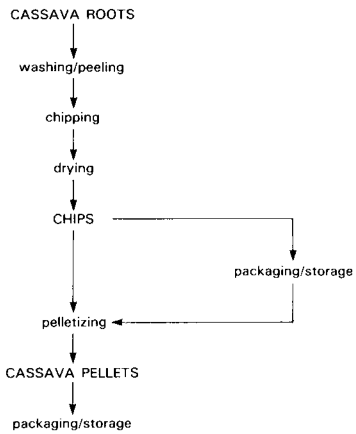

Fig. 30. Flow sheet for chip and pellet production.

12.5.2.1 *Processing*

About 2.5-3 tonnes fresh roots are required for 1 tonne of pellets giving a conversion rate of 33-40%. The first step can be washing and peeling. In Indonesia this is common but in Thailand and Malaysia these steps are usually omitted. This leads to an increase in the conversion rate but dirt and peels reduce the quality. After washing, a dip in a 3% solution of lime may be used to neutralize the acid juice and prevent deterioration.

Chipping can be done by hand, as is common in household processing, or by simple machines. These usually consist of a driven disc with radial chipping slots fitted with cutting blades. The size of the chips varies but generally the dimensions fall within the following ranges: thickness 3-6 mm, width 6-10 mm, length 100-250 mm. The chips are usually dried in the sun on floors which may be painted black for better absorption of radiant energy. Drying to 140 g water/kg product moisture content takes about 8-9 hours full sunlight (on average 1.5-3 days). Drying on wire mesh racks takes longer (14 hours full sunlight) but is more uniform. The labour requirements for sun-drying are about 35-40 labourers per hectare of drying floor. Mechanical drying is also used but it is considered more expensive. Bin driers operating at 70-80 °C require an energy input of 300 kW for 24 hours to dry 10 tonnes of chips from 700 to 140 g water/kg moisture content. In larger plants revolving drum driers are used.

Pelletizing is done in continuous die presses with capacities from 2 to 8 tonnes per hour. In Thailand and Malaysia these presses are often made locally, but they are usually of poorer quality than those imported from Europe. The chips are forced through small holes in the die causing a rise in temperature through friction. This gives the pellets cohesion, but also causes considerable wear on the die and makes pelletizing energy intensive (about 60-140 kWh per tonne). The best results are obtained with rather small chips (130-140 g water/kg or 13-14% moisture content) which are heated to 65 °C and moistened to 15-17% just before pressing. After pressing, cooling is necessary. The moisture content then drops to 14%. Chips pressed at moisture contents below 14% give burned pellets, while soft pellets that crumble in transport are obtained if the moisture content exceeds 17%. Soft moist pellets and pellets adulterated or contaminated with sand, chalk or foreign matter often cause serious problems in transport and handling in the export trade.

12.5.2.2 *Evaluation of starch, chip and pellet production technologies*

If introduction of cassava processing is to be considered, or if existing industries are to be improved, a decision on the type of product and manufacturing scale and technology used must be made. This decision should be based on an evaluation of relevant criteria that can be derived from the type of information presented in the earlier sections. The importance attached to the various criteria will depend on the problem formulation, the specific situation in which the problem is set and the value judgement of those who have to make the final choice. In the following discussion of the various criteria (technical, economical, etc.) that may be used for evaluating alternatives no distinction is therefore made between 'must' and 'want' criteria as this will largely depend on the specific situation.

Technical, ecological and management aspects

The supply of raw materials is of particular importance. Criteria are the total cassava requirement, the area under cultivation necessary to provide this amount and the regularity of supply. The estimated raw material requirements for starch and pellet production at different scales are presented in Table 21. There are three ways to fulfill these requirements; by plantation farming, buying from small holders or by using both sources.

Plantations provide a continuous and planned supply of high quality roots produced at higher yields per hectare. They require however a considerable area, large investment, a large labour force and competent management. Local land ownership customs may prevent the establishment of a plantation. In many parts of West Africa for instance, the community or tribe is traditionally the owner of all land. Large factories in general require the establishment of a plantation in their immediate vicinity.

Cassava production by small-holders is in certain respects a less efficient option. The lower agricultural inputs tend to a lower yield of fresh roots per hectare. The transportation of the roots from the dispersed smallholdings to the central factory places higher demands on roads and vehicles and requires communication between the producers and the processor. Small holder production may ensure a fairly even distribution of income and fits in with the establishment practice of subsistence farming. Small and intermediate factories can rely on small holder production and thus contribute to a balanced rural development and avoid land ownership problems.

The competition for the same raw materials that may arise between starch production, chips and pellets and traditional food uses may require government control in agriculture production. The likeliness or necessity of such government interference can be another criterion.

In Table 22 various other technical criteria for the assessment of different starch production processes are presented.

Large-scale processes make more efficient use of the raw materials as shown by the starch recovery rate and the conversion rate. The higher rate of conversion of cassava root into starch also leads to lower handling costs per tonne end product.

The labour productivity (in tonnes starch per person per year) in a large starch factory is higher than in a small or intermediate unit. In instances however where the creation of employment is intended, this can be better provided by small and intermediate factories. Two intermediate technology plants of 1000 tonnes per year will employ up to 30 people more than

Table 21. Estimated raw material requirements and necessary cultivated area.

Scale of production	Raw material required (t/d)	Operating period (d/y)	Raw material required (t/y)	Yield of tubers (t/ha per y)	Cultivated area required (ha[1])
Starch small	1.0	150-170	150-200	10	15-20
Starch intermediate	6-30	250	1500-7500	10	150-750
Starch large	40-100	250	10000-25000	15	700-1700
Chips pellets small	10	200	2000	10	200
Chips pellets large	56	250	14000	15	1000

1. No allowance is made for the fact that after five years cultivation the land needs a rest period.

Table 22. Comparison of technical data on starch processing at different scales. (data from Würdemann et al. (1979), Grace (1977), Edwards (1974) and plant manufacturers' information)

Criteria	Small scale	Intermediate scale	Large scale
Raw material required (tonne/year)	150 - 200	1 500 - 7 500	10 000 - 25 000
Production starch (tonne/year)	30 - 40	270 - 1 350	2 000 - 6 250
Recovery rate of starch (%)	50 - 70	60 - 70	75 - 93
Conversion rate produce/input (%)	20	18	20 - 25
Number of employees	4	40	50 - 60
Production per employee (tonne/year)	7.5 - 10	6.5 - 33	33 - 125
Required operating skills	low	low	high
Percentage of unskilled labour (%)	75	70	42
Use of energy			
Electricity (kwh/starch)	-	(not essential)	100 - 175
Fuel oil (tonne/tonne starch)	0.02	0.02	0.04 - 0.07
Use of water (m^3/tonne starch)	25	43	12 - 35
Quality of product	Variable, good to reasonable - not for export	Reasonable - not for export	Good - export quality
Origin of machinery and equipment	Locally made	Locally made	Imported
Maintenance requirements	High	Medium	Medium
Origin of spare parts	Local	Local	Imported
Organisational complexity	Small	Small	Moderate
Amount of waste produced			
- pulp and peel (tonne/year)	100 - 130	1 150 - 5 780	20 000 - 50 000
- waste water (m^3/year)	750 - 1 000	11 250 - 56 250	80 000 - 160 000

one large unit with an annual capacity of 2000 tonnes starch. Smaller plants also provide the opportunity of creating employment in several separate areas.

Large-scale processing may be efficient in the use of energy, but because of more energy intensive equipment and hot air drying of the product, the total energy requirement is much greater than that for plants relying on sun-drying. The availability reliability and costs of energy sources will affect the choice of equipment for processing. Large scale plants require stand by generators to compensate for irregularities in electricity supply. They generally rely on more expensive forms of energy.

It is very difficult to produce starch of the constant quality required for export by any technology other than large-scale processing. For the local market, however, it has been found in at least one instance that starch produced in large-scale factories is not so acceptable as that manufactured by other technologies. In Indonesia, cassava starch is used in the manufacture of fish crackers or 'krupuk'. These crackers are made by mixing fish paste with starch to form a dough which is then thinly sliced and dried. Before eating the dried slices are deep-fried in hot oil which causes them to expand into large puffed crackers. The degree of expansion, which is an important quality characteristic, depends on the quality of the starch. It has been found that 'flash' dried starch gives a lower expansion of the krupuk than sun-dried starch. This may be associated with changes in the starch structure during high temperature drying (Würdemann et al., 1979). In this case starch produced by intermediate-scale factories, is preferred to that from large-scale plants.

Starch production requires a regular supply of good quality water. On a large scale, purification and re-utilisation of water are feasible hence the water requirement and effluent production per tonne starch may be reduced in large starch factories to a level below that for other production processes.

The problems of waste utilisation and disposal depend on the production process, the treatment capacity available and the location of the factory. Large amounts of concentrated waste pose the most serious threat to the environment, but they can be more effectively treated and re-utilised than dilute effluents. It follows that large-scale factories will have to operate effluent treatment plants and take steps to ensure safe disposal of the wet peel and pulp.

Small and intermediate scale production units are locally built and do not require foreign currency for their establishment and maintenance. This can be a great advantage if foreign exchange is difficult to obtain. If the foreign currency obtained by a large scale factory exporting starch is made available to the management it should not be difficult for them to buy spare parts, but it is usually not government policy to pass foreign earnings back to the company that generated them.

Economic aspects

There are not many comparative economic studies on the processing of cassava by different methods. Edwards (1974), however, has published a study on the manufacture of starch, chips and pellets in South East Asia which, he suggests, can be used as a guideline for operations in other parts of the world (Table 23).

Edwards chooses the 'yearly rate of return on investment' and the 'nett present value' as the main criteria for evaluating the economic success of a project. These give an indication of the period over which the investment repays itself and the money value for the project over its lifespan taking into account the expected rate of interest for capital. Various other econom-

Table 23. Economic comparison of the industrial production of cassava starch on large scale with (G) and without plantation (F) and on intermediate scale (H). Values in £ sterling 1972-1973. (from Edwards, 1974)

	Model F	Model G		Model H		
	2 shifts	3 shifts	3 shifts	1 shift	2 shifts	3 shifts
Capacity (tonne starch/year)	9675	9675	9675	1605	1605	1605
Capacity utilisation (%)	66	100	100	33	66	100
Production (tonne starch/year)	6450	9675	9675	535	1070	1605
Total investment	362660	362660	537360	32460	32460	32460
Return (+) on investment (-) per year (%)	+1.8	+12.0	+11.5	-11.5	-1.8	+7.7
Nett present value (discounted at 8% over 13 years)	-144290	+116980	+261160	-48130	-23290	+990
Total labour force	54	68	133	15	26	37
Investment per labour-place created	6716	5332	4040	2164	1248	877
Production cost per tonne starch	37	33	31	45	38	36
Revenue/Labour costs (factory only)	10.00	12.50	12.50	3.12	4.20	4.76
Return (+) on investment (-) per year with correction for yield	+7.2	+19.1	+17.0	-11.5	-1.8	+7.7
Internal rate of return (%)	-	17.7	20.8	-	-	10.5

Table 24. Estimated costs for the production of cassava starch on three different scales. Values in £ sterling 1979. (adapted from Edwards 1974; Würdemann et al. 1979)

	Large scale	Intermediate scale	Small scale
Investment costs			
1. Land and site preparation	66292	6250	125
2. Buildings	20933	2917	250
3. Plant and equipment	250000	6467	799
4. Working capital	37668 +	2917 +	208 +
5. Total investment	374893	18551	1382
Annual operating costs			
6. Raw materials	420000	30000	2550
7. Labour	8417	3480	493
8. Energy, Transport	19167	200	28
9. Maintenance	4500	568	26
10. Interest on working capital	7917 +	613 +	43 +
11. Total annual operating costs	460001	34861	3140
12. Revenues	542083 −	42208 −	3896 −
13. Operating surplus	82082	7347	756
14. Taxes	20208 −	1367 −	126 −
15. Nett profit or annual cash flow	61874	5980	630
Operating period per year	290	200	170

ic criteria may however also be used to analyse the effects of a certain scale of operation and technology used. The labour productivity of the factory workforce, for instance, expressed as revenue divided by labour costs, has been calculated from Edwards' data for each situation. Also the required investment per labourplace created and the Internal Rate of Return are shown.

A brief comment on some of Edwards' assumptions is necessary before drawing one or two tentative conclusions. The estimate of 290 days' operation per year for all models may be rather high in certain cases. Intermediate-scale factories usually operate in a traditional social and cultural environment and close during religious holidays and other festivals. The possibility of raw material shortage causing under-utilisation of production capacity, a particular problem of large factories, is not given adequate consideration. The recovery rate and quality of starch obtained from different processes is not always reflected in the calculations.

In general, large-scale factories can operate on an acceptable financial basis because of the lower production costs achieved by economies of scale. Intermediate-scale operations may also be satisfactory. They have the additional advantage of creating from a low initial investment. The achievement of a full utilisation of the production capacity by organisation of raw material supply and shift working is most important for both scales of operation.

Data on the economics of village and household cassava starch production have been published by Würdemann et al., (1979). The figures for small and intermediate-scale processing were obtained from a field study in Indonesia, and the values for large-scale operations were adapted to the Indonesian situation from the data of Edwards, (1974) (Model F with 2 shifts in Table 23). A breakdown of costs is presented in Table 24, and from this various economic parameters have been calculated (Table 25). Capital productivity is represented by the nett present value, the internal rate or return and the investment per tonne of starch produced. These criteria refer only to the function of capital. To consider the role of other inputs, such as energy and labour, these are also related to the amount of starch manufactured.

The figures in Table 25 indicate that by most of the economic criteria the intermediate-scale operations are most attractive with small-scale manufacturing also performing well. The internal rate of return and the investment per tonne of starch produced indicate that of all three scales of operation the intermediate has the highest capital productivity. The potential of traditional and post-traditional operations is often underestimated and in general the highest capital productivity will be obtained in the informal sector. Research would be necessary to prove this.

A comparison of the studies of Edwards (Table 23) and Würdemann et al. (Table 25) is unfortunately not very revealing. Although the results are presented in an exemplary manner, the situations for which the calculations were made differ considerably, so that figures for an intermediate technology plant cannot be meaningfull compared, particularly with respect to total investment.

Even when data and calculations have been adapted for a specific situation, their value is limited. Gathering reliable data is very difficult in many developing countries and the quality of data used determines the dependability of results calculated from them. The situation may change so quickly that in a short time the results of the study become inapplicable. The techniques of 'risk analysis' and 'sensitivity analysis' (Price Gittinger, 1972; UNIDO, 1978) have been developed to minimise this problem. Often the actual results of such calculations cannot be directly applied but the insight into economic aspects and risk factors may be valuable.

Table 25. Comparison of estimated economic characteristics for the production of cassava starch on three different scales. Values in £ sterling 1979.

	Large scale	Intermediate scale	Small scale
Total investment (£)	374893	18551	1382
Annual cash flow (£)	+61874	+5980	+630
Producing life (years)	13	10	5
N.P.V. at 18%[1]	-13934	+11154	+799
I.R.R. (%)	16.5	46	50
Tonnes starch produced:			
per year	6450	440	45
during total operating life of plant	83850	4400	225
Investment per tonne starch produced (£/tonne)	4.47	4.22	6.14
Energy and transport cost per tonne starch (£/tonne)	2.97	0.45	0.62
Total number of employees	54	39	4
Labour cost per tonne starch (£/tonne)	1.30	7.91	10.96
Investment per labour place (£/man per year	534	48	69

1. In 1979 the expected interest rate for short-term capital in Indonesia was 18%.

Edwards' (1974) study also makes a comparison of the economics of starch production with those of chip and pellet manufacture. The results are summarised in Table 26. It was assumed for both large and intermediate scale chip production that sun-drying would be adequate. This explains the relatively low energy costs for chip and pellet manufacture. The tentative conclusion that emerges from these model calculations is that intermediate scale chip production and large-scale pellet manufacture seem attractive alternatives to starch processing both in terms of employment creation and economic viability.

In practice there can be direct competition for cassava tubers between the processing industries. An example of this occurred in the Sukabumi region of West Java, Indonesia (Würdemann et al., 1979). Cassava is a reserve food crop in this area and there was a local industry of 20 intermediate and about 60 small-scale starch producing plants utilising the excess roots supplied by small-holders. Chips were not produced in any significant quantity until 1979 when a merchant obtained an export contract for them. He started collecting chips from household processors and within a few weeks the production of chips had increased to such an extent that the starch processors could not obtain cassava tubers despite doubling the price offered from 10-20 Rupiahs per kg. As it was the dry season, chips could be produced by sun-drying and the price of 45 Rupiahs per kg obtained with very little expenditure. At a raw material conversion rate of 53%, this is equivalent to a price of 24 Rupiahs per kg fresh root. The farmers consequently sold all their reserve cassava food stocks, thereby increasing the risk of famine if the harvest of the main food crop rice failed. The outcome for starch producing plants was disastrous; permanent employment positions and the market for cassava were put in jeopardy. In such cases government control by subsidies or the withdrawal of licences may be necessary.

Table 26. Comparison of the production of starch, chips and pellets on different scales. Values in £ sterling 1972-1973. (from Edwards, 1974)

	Large scale			Intermediate scale	
	Starch (Model F) (2 shifts)	Chips (Model B) (2 shifts)	Pellets (Model C) (2 shifts)	Starch (Model H) (2 shifts)	Chips (Model A) (2 shifts)
Raw material requirements (tonnes/year)	28000	28000	28000	4640	4000
Product output (tonnes/year)	6450	9800	9800	1070	1400
Total investment	362660	91140	151620	32460	13080
Annual cash flow	+27630	-2920	+24090	+1160	+3150
Annual rate of return on investment (%)	+1.8	-9.0	+9.9	-1.8	+18.8
Nett present value (8%, 13 years)	-144290	-114210	+38770	-23290	+11820
Total labour force	54	51	67	26	18
Raw material processed per labourer per year (tonnes)	518	549	418	178	222
Revenue/labour costs	10.00	12.94	13.55	4.20	6.31
Investment per labour place	6716	1787	2263	1248	727
Energy costs per tonne raw material processed	1.02	0.16	0.55	0.89	0.22

Socio-political aspects

Socio-political criteria such as the distribution of profits on cassava processing between all members of the chain from farmer to retailer or exporter must also be considered when an operation is established. The implications of providing an outlet for cassava may be wider than initially foreseen.

If a large processing factory is established its products compete in the market with those of smaller industries and can lead to their downfall. This directly affects small holders in outlying areas who normally supply rural industry. The output of a cassava processing plant must be acceptable to its target market. Where traditional uses exist, smaller industries using improved traditional technologies may be more able to provide an acceptable food than large factory (see p. 137 'krupuk'). This problem can also arise in situations where it is hoped to open a completely new market. In Nigeria for instance, a modern large-scale starch producing factory in the east of the country found little demand for its product, good quality native starch. The establishment of a smaller factory with a starch modification plant might have been more successful (personal communication H. Stassen, Amadu Bello University, Zaria, 1977).

12.5.3 Gari

Gari is a fermented dried cassava flour that is traditionally produced in West Africa. Although it is known all along the West African coast, it is most popular in Nigeria where the yearly consumption is estimated at 1.6 million tonnes (Cook et al., 1975). As most research on the production, processing and marketing of gari has been done in Nigeria we refer mainly to the situation and experience in that country. Gari is very similar to the South American farinha. The essential difference between gari and farinha is in the extent of the fermentation. In Figure 31 is shown the basic process for gari.

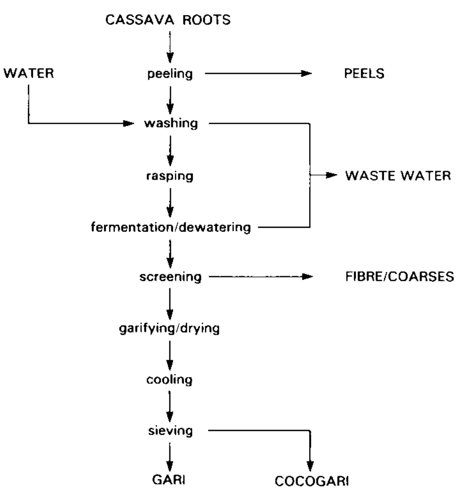

Fig. 31. Basic process for gari manufacture. (from Cook et al., 1975; Williams, 1978)

To avoid having too much fibre in the final product, cassava for gari processing must be peeled to completely remove the cortex. After washing, the roots are rasped to give a slightly coarser pulp than that required for starch processing.

Fermentation takes place in two phases. Initially the starch is hydrolysed by Corynebacterium manihot to give sugars. These are metabolised to organic acids which hydrolyse the cyanogenic glucosides of the cassava and release HCN. When sufficient acid has been formed the second phase characterised by Geotrichum candida growth, begins. From the sugars the mould produces the aldehydes and esters that give gari its typical flavour.

De-watering by pressing, may be done during the fermentation or afterwards in a separate operation. Some soluble cyanide and organic acid is removed with the press-liquid. The moisture content is reduced from 65% (w/w) to about 50%. The de-watered mass is usually screened to remove fibres and coarse material to obtain a loose damp flour. The term garification is used for the partial gelatinization of this material on a hot surface. Heating is prolonged to give a dry flour which, when cooled, can be kept for 2 to 6 months or more. The shelf life depends on the moisture content and the storage conditions. The dried product is usually sieved into two fractions: high quality gari with a particle size of 0.15-2.00 mm (400-4000 m^{-1}), and cocogari which contains the coarse fraction fibres and lumps. Cocogari is usually ground to a flour.

Gari is consumed in the form of a dough (Eba), or as a thin porridge. Both are prepared in the household by mixing dry gari with hot or cold water and cooking. Gari is an important staple for the common people and is still mainly produced by women at household or village level. Urbanisation and changes in life-style however, have created an increasing demand for processed and packaged gari. As transport of dry gari is cheaper than that of fresh roots, processing takes place in rural areas and small towns. To meet the urban requirements, an increase in productivity and/or scale of production has become necessary. This has resulted in the development of mechanised processing, both at an intermediate scale by a 'post-traditional' process, and at a larger scale by a 'modern' process (Ngoddy & Kaplinski, 1976; Ngoddy, 1976 and 1980).

12.5.3.1 *Traditional production, processing and marketing*

Traditionally gari is produced manually in Nigeria by women and girls (Williams, 1978). In some parts of the country 50-75% of the women are full-time processors. About 50-70% of the raw material comes from farms in the immediate vicinity of the processors, the rest from farms at a greater distance. 34-42% of the gari processors depend on their own farms for the supply of cassava roots (Cook et al., 1975). The raw material is usually carried on the head to the processing site.

Small-scale processing follows the sequence of operations already presented in Figure 31. The roots are peeled by hand with a knife. The whole cortex is removed (peeling losses 20-35%). About 37 kg cassava can be peeled per hour by one person.

After washing to remove soil, the roots are rasped by hand or in a simple motor driven roll-rasp similar to those used for starch processing. Sometimes a group of processors owns a rasping machine. There are also mobile rasping machines operated by men who travel from village to village where, for a fee, they rasp the tubers for women processors.

Fermentation and de-watering are done in one operation. The wet pulp is put into a woven bag and pressed either by placing heavy stones on it or by trussing it up on a press frame. Fermentation and pressing take 3 to 5 days.

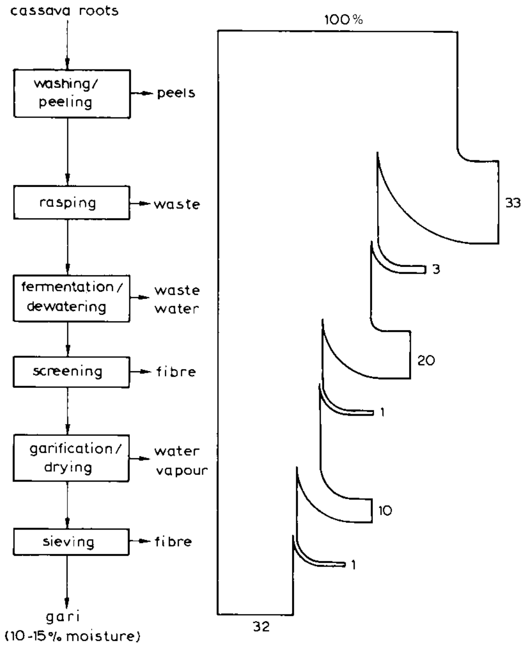

Fig. 32. Estimated mass balance for gari production.

The pressed cake is screened by hand through a coarse woven mesh to break up lumps and remove fibres.

Garification and drying are combined in 'frying' of the gari. Frying takes place in a wide shallow pan above a wood fire. The material is continuously moved over the pan surface and reaches a temperature of 80-85 ^{o}C. Rapid heating partially gelatinizes the gari and as the moisture content decreases the product is dried by contact with the hot surface. A trained processor can produce about 2.3 kg per hour. The quality depends on the skill and judgement of the processor. If the gari is still moist it is sun-dried, otherwise it is left to cool giving a free flowing flour with a moisture content of 10-15% (w/w).

In Figure 32 an estimated mass balance for traditional processing is given. On average 90 hours are required to produce a 100 kg bag of gari from the harvested roots. Peeling and frying of the wet pulp are the most time consuming operations (65% and 24% respectively of total processing time). Productivity will therefore increase most by mechanisation of these two operations.

Most of the gari is sold to traders, usually women (92%), who limit their trade to local markets. About 35% of the traders buy and sell at the same market. Because of transport costs their is little trade between towns.

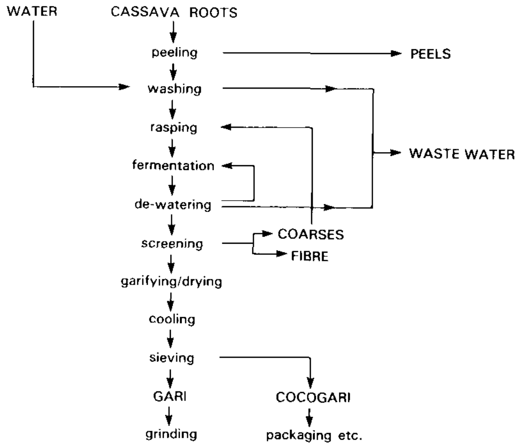

Fig. 33. Flow sheet for post traditional gari production processing.

12.5.3.2 *Post-traditional production*

Innovations in gari processing started in the fifties with the introduction of locally made mechanical rasps, and multi-place frying ovens. On the basis of these early developments modern mechanised processing evolved under the auspices of the Federal Institute for Industrial Research (F.I.I.R.) in Nigeria (Akinrele et al., 1962a; Akinrele et al., 1962b; Adeyinka & Akran, 1964). During the Nigerian Civil War (1966-1970) two separate groups of technologists (Proda and Fabrico) developed similar 'intermediate' or 'post-traditional' systems. In Ghana (Wadhai, 1973) and in Brazil post-traditional manufacture of fermented cassava products is also known to exist. Today in Nigeria, several post-traditional gari factories are operating using machinery from the small company Fabrico (Ngoddy, 1976, 1980; Ngoddy & Kaplinsky, 1976). This type of factory is taken as an example.

In post-traditional operations rasping and frying are mechanised. Fermentation and de-watering are separate processes. Liquid expressed during de-watering acts as a starter culture and accelerates the fermentation. The flowsheet is shown in Figure 33. The estimated mass balance is the same as for traditional processing (Figure 32).

Post-traditional production takes place in small factories with an output of about 1 tonne of gari per day. Cassava (about 3.5 tonnes per day) is bought from small-holders or obtained from factory-owned plantations. Roots are collected and transported by truck. The cassava is usually peeled by hand. Recently an abrasive peeling machine has been introduced that is particularly useful for peeling smaller roots. After hand washing the roots are rasped on roll rasps similar to those used in traditional processing.

Fermentation is done in aluminium or plastic vats or in woven nylon bags after adding some press liquid from earlier batches; it takes 2-3 days.

De-watering is done by hand in simple screw presses. These consist of a concrete slab with a bolt embedded in each corner. A wooden frame which runs along the bolts is put under pressure by large wing nuts. Similar presses using heavy duty jacks to apply the pressure are also in use. Bags of wet pulp are placed on the base and the liquid expelled by pressing drains through channels in the concrete. The pulp is de-watered to about 50% (w/w) moisture in 1 hour.

After sifting through a hand operated drum screen, the moist fermented pulp is garified and dried in a mechanised gari fryer. This machine is the most significant innovation in the post-traditional process. It consists of a semi-cylindrical steel trough (diameter 0.75 m, length 3-4 m) placed in a wood or coal fired oven. Mounted in the trough, is a coaxial shaft fitted with paddles that scrape the heated surface. The shaft is rotated at 250-500 kg^{-1} (or 15-30 r.p.m.) by a small electric motor. The material is fed into the trough at one end and transported by the paddles down a gentle slope to the outlet at the other end. The machine imitates the traditional frying procedure but operates continuously. The action of the paddles improves heat transfer, mixes and transports the gari, and prevents caking. The material is often passed through the machine again after a rest period to give a better quality gari. The machine which can be operated by two unskilled (women) labourers has an output of about 65 kg gari per hour. The gari is cooled, sieved into fractions, packaged in heat sealed plastic bags and stored for transport and distribution.

An operation of this capacity employs about 45 people per shift including management personnel. Marketing of the gari is done by factory owned companies. It is sold mainly in urban supermarkets to people in the higher income bracket.

12.5.3.3 *Modern production*

The modern fully mechanised process for gari production was developed by the Federal Institute for Industrial Research, Oshodi, Nigeria, where in 1951 research in this field started. In 1962 a pilot plant with a capacity of 1 tonne of gari per day was established. In the following years improvements in energy use and product quality were made (Adeyinka & Akran, 1964; Akinrele et al., 1962a,b), and larger scale processing equipment was developed (10 tonnes gari per 24 hours) in co-operation with a British machine manufacturer (Newell Dunford Engineering Ltd., Surbiton, Surrey, U.K.) (Anon., 1974). The first commercial plant of this type came into production in 1977.

The modern process is characterised by the mechanisation of all unit operations and by the use of conveyor belts and pneumatic transport. The fermentation time is reduced by inoculation with starter culture obtained from earlier batches, while garifying and drying are done in separate machines (Ngoddy & Kaplinsky, 1976; Anon., 1972, 1974).

The modern mechanised process now operating in Nigeria has a capacity of 450 kg of dry gari per hour corresponding to a raw material requirement of 2200 kg cassava roots per hour. (Estimated conversion rate 20-25%) (Anon., 1974). Full capacity utilisation (i.e. 300 days per year, 3 shifts of 8 hours requires a cultivated area of 1600 hectares to ensure a regular supply of raw material. This assumes a yield of 25 tonnes per hectare per annum and allows for crop rotation (anon., 1974). A factory plantation or well organised co-operative is required to provide this amount. Processing follows the flowsheet in Figure 34.

After transport to the factory, the roots are peeled and washed in rotating abrasive drums. Mechanical peeling gives irregular results and leads to relatively high peeling losses. Peels and washing water are flushed out of the factory and separated by screening or settling in a pit. The peeled roots are disintegrated in a hammermill and the mash is mixed with fermentation liquor from the former batch (about 4 days old). Fermentation takes

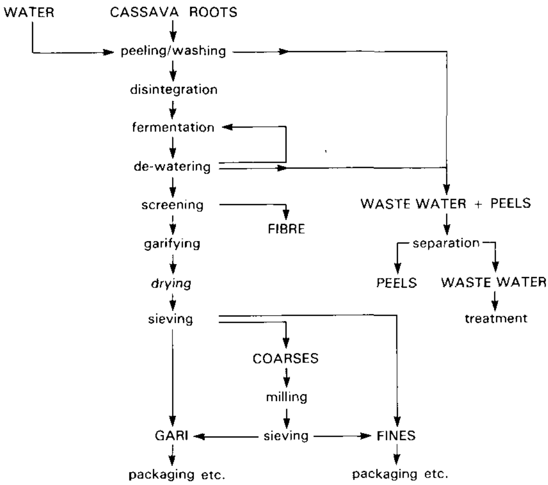

Fig. 34. Flow sheet for modern gari processing.

place in woven nylon bags placed in large vats (1 tonne per vat), and lasts 3-4 days. After de-watering in horizontal hydraulic presses, the bags are emptied into a 'lump breaker' and passed over a screen which removes coarses and fibre. The material is then fed by a constant rate feeder to the specially developed 'Garifryer' (patented). Here the material is gelatinized in a rotating cylinder heated externally by oil burners. The gelatinized gari is then fried in a rotating cascade drum drier (parallel flow) to about 8% (w/w) moisture content. After drying, the product is milled and sieved to obtain the required particle size range.

In the factory a total of 83-85 people are employed of whom 80 work in shifts. (3-5 daily workers including management and 20 workers per shift, 3 shifts + 1 reserve shift). The product is distributed to urban supermarkets and is bought by the same clientele that purchase post-traditional gari.

12.5.3.4 *Evaluation of gari technologies*

There are several publications in which a comparison is made between different technologies and scales of production for gari. The most recent is by Ngoddy (1980) in which he reports on the situation in Nigeria in 1979.

A post-traditional operation (Fabrico system), a modern fully mechanised plant (Newell Dunford/F.I.I.R. system) and an assumed co-operative having the same output as the intermediate factory but using the traditional labour intensive method are compared. Although the output of the co-operative has been assumed, Williams (1978) reported that in 1977 there were groups of 8-13 women producing gari on an experimental basis in four Nigerian villages. Other such groups are known to exist or to have existed elsewhere in Nigeria.

Technical aspects

The main characteristics of the three technologies are summarized in Table 28, while Table 29 shows the inputs required and the expected outputs.

Table 27. Composition and recommended quality specification for gari. Proximate composition of unprocessed cassava and gari. (from Ngoddy, 1980)

	Peeled root	Village gari	Industrial gari
Water (%)	71.50	14.2	8.4
Nitrogen free extract (%)	26.82	81.8	87.0
Crude fibre (%)	0.12	1.4	2.3
Fat (ether extract) (%)	0.13	0.1	0.1
Ash (%)	0.69	1.4	0.9
Calcium (mg/100 g)	33.0	17.7	45.6
Phosphorus (mg/100 g)	80.0	57.2	56.9
Iron (mg/100 g)	0.07	2.0	2.2
HCN (mg/kg)	-	19.0	10.0

Recommended quality specifications

Moisture content max.	8 - 10 (%)
Swelling test	300 - 500 (% volume increase)
Total acidity	0.8 - 1.2 (%)
HCN	20 (mg/kg) Village gari
	10 (mg/kg) Industrial gari

Recommended screen sizes for gari

Tyler screens are to be used for classification

(i) *Standard size gari particles*
99% of gari particles to be between 16 and 32 mesh;
90-95% of particles must pass the 24 mesh screen

(ii) *Fine size gari particles*
90% of gari particles to be between 65 and 150 mesh;
90-99% of particles must pass the 100 mesh screen

The modern technology requires the largest amount of raw materials, but this is produced on a smaller area (Table 29). This is only possible if cassava is produced (at least partially) on a factory plantation. In view of the amounts required, the other technologies can rely on smallholder farmers. Also occasional interuption of the production due to failures of supply have less serious consequences for the traditional and intermediate operations.

The comparison in Table 28 shows that the three technologies differ mainly in the degree of mechanisation and the sophistication of machinery. An increase in mechanisation may be expected to lead to more efficient processing in terms of conversion rate, labour productivity and the use of energy and water. The figures in Table 29 show that this holds true for traditional versus intermediate processing. Amazingly, however, the conversion rate of cassava into gari is lower for the modern technology then for the other two options. This is caused by the higher peeling losses in mechanical peeling. This type of peeling has the additional disadvantage over hand-peeling that the wet slurry of peels produced can be less easily used as animal feed. The mechanized abrasive peeling also accounts for the higher consumption of water in modern processing.

As no exact figures can be given for the fuelwood consumption in traditional and intermediate processing, the energy efficiencies can not be

Table 28. Three technologies for the production of gari. (from Ngoddy, 1980)

Stage	Traditional labour intensive	Post-traditional intermediate	Modern fully mechanised
1. Raw material production and supply	Smallholder production Yield: ¢ 10 (t/hectare per year	Smallholder production Yield: ¢ 10 (t/hectare per year	Factory plantation and/or smallholder co-operative Yield: ¢ 10–25 t/hectare per year
	From traders	From traders	From purchasing agents on factory plantations
2. Peeling and washing	Manual: 38 kg/man-hour, 25% raw material loss	Manual: 38 kg/man-hour, 25% raw material loss	Mechanical abrasive peeler, 30% raw material loss
3. Size reduction	Manual: 23 kg/man-hour, Mechanical: 200 kg/hour	Manual: 23 kg/man-hour, Mechanical: 200 kg/hour	Mechanical: hammer mill (imported), 1500 kg/hour
4. Fermentation	Fermentation and dewatering in heavily weighted cloth or nylon bags	Batch fermentation in (aluminium) tanks	Batch fermentation in (aluminium) tanks
5. Dewatering	See 4 above	Semi-mechanised: locally made hydraulic or mechanical press	Mechanised: hydraulic press
6. Screening	Manual: woven fibre screen	Semi-mechanised: locally made screen with hand or mechanically driven paddle	Mechanised: motorised rotary screen
7. Garification	Manual: cast iron pan over wood fire (combined stage with drying): 2.2 kg/man-hour	Semi-mechanised: locally made wood-burning fryer (combined stage with drying): 70 kg/man-hour	Mechanised: rotary kiln heated by oil burners 450 kg/hour
8. Drying	See 7 above	See 7 above	Mechanised: rotary drum drier
9. Milling and sieving	Not necessary	Milling: not required Sieving: locally made hand or mechanical sieve	Milling: disc mill Sieving: vibrating multi-deck sieve

10. Packaging	50 kg jute sacks	50 kg heat sealed polyethylene bags	50 kg heat sealed polyethylene bags
11. Material handling (all stages)	Manual	Manual, with trolleys	Belt conveyors, bucket elevators with trolleys
12. Marketing and distribution	Through traditional gari trade system in local markets	Through traditional trade system and supermarkets	Through traditional trade system and supermarkets
13. Purchasers	All income groups, rural and urban	Mainly urban higher income groups and institutions (e.g. schools, army)	Mainly urban higher income groups and institutions (e.g. schools, army)
14. Buildings	600 m^2	200 m^2	650 m^2
15. Employees per shift			
Total	234	45	28
Unskilled	229	40	9
	predominantly female		predominantly male

Table 29. Output and inputs for three gari processing technologies. (from Ngoddy, 1980)

	Traditional labour intensive	Post-traditional intermediate		Modern fully mechanised	
Number	1 shift[1]	1 shift	3 shifts	1 shift	3 shifts
Equipment	Manual with mechanical rasping	semi-mechanised		Fully mechanised	
Labour force	234	45	135	28	83
Cassava (tonnes per year)	3300	3300	9900	4400	13200
Required minimum cultivated area (hectares)	330	330	990	176	528
Annual output of gari (tonnes per year)	1100	1100	3300	1100	3300
Conversion rate (tonnes gari per tonne cassava)	0.33	0.33	0.33	0.25	0.25
Labour force per tonne of gari per year	0.070	0.014	0.014	0.006	0.006
Water (m^3 per tonne of gari)	6.52	approx. 0.45		2.73	
Electricity (kWh per tonne of gari)	(not absolutely required)	7.3		30.0	
Fuel (litres per tonne of gari)	(mainly wood)[2]	(mainly wood)		31.8	

1. Number of 8-hour shifts per day.
2. Assumed to be double the input for the intermediate technique.

compared. The modern technology however uses more expensive forms of energy (i.e. in Nigerian conditions) as can be seen from the costs of energy in Table 30.

The labour productivity in modern processing is highest as can be expected (Table 28). The required skill level is however much higher as in traditional and intermediate processing. This is also reflected in the cost of labour per tonne of gari produced (Table 30). The required higher skills and training may be an advantage in terms of quality of employment, but it may present recruitment problems in rural areas. Also it may have serious consequences for the employment and income position of rural women who are the traditional (and post-traditional) processors.

An advantage of the modern processing is the possibility to guarantee a more constant, and better product quality (e.g. in terms of moisture content and HCN level, see Table 27). As quality is however very much a subjective matter, much attention should be paid to producing a locally acceptable product.

Economic and management aspects

In the present Nigerian situation, for the investor/entrepreneur the intermediate-scale post-traditional production of gari is the most favourable option. It has good labour productivity, the lowest investment per unit output and a low production cost, while not being particularly sensitive to the capacity utilization (1 shift versus 3 shifts).

A cost comparison of the post-traditional and modern processes can reveal the reason for the apparent superiority of the less sophisticated operation and also indicates areas where further development is needed (Table 30).

The relatively high prices of the imported garifryer and drier units combined with their low capacity, increase the investment necessary in a fully mechanised factory to obtain a given output. As raw material costs represent 40-60% of the total production costs for both systems, the lower conversion rate obtained with the modern process (due to high peeling losses) significantly reduces its productivity. The poor technical efficiency of these processes is also reflected by the high cost of services (water, energy) for these operations.

The labour productivity (labour costs per tonne gari) of both operations are similar despite the different numbers of employees involved. The average annual salary of workers in an intermediate plant is 1355 Naira and in a modern factory 1540 Naira. The modern factory employs organised skilled labour but the intermediate operation can obtain unskilled casual labourers readily in rural areas.

The lower reliance of post-traditional operations on existing infrastructure is an advantage. As can be expected in a developing country many parts of Nigeria still suffer frequent breakdowns in the supply of water, electricity and fuel, while the road network, although impressive is not yet very dense.

Social aspects

Factors such as the total employment created, investment per job and the quality of employment are of national importance. Nigeria for instance, will soon have a large number of well educated aspiring school leavers looking for jobs. Solutions to other potential problems, such as deforestation caused by the excessive use of firewood for traditional and post-traditional processing operations, must be found now before their magnitude exceeds the nation's capabilities.

It might be expected that mechanised processing will increase at the expense of labour-intensive operations. In the longterm, this may indeed be

Table 30. Investment costs and annual costs. In Nigerian Naira 1979: 1 Naira ≈ 2 US $. (from Ngoddy, 1980)

	Traditional labour intensive	Post-traditional intermediate		Modern fully mechanised		Cost ratio modern post-traditional
	1 shift[1]	1 shift	3 shifts	1 shift	3 shifts	1 shift
Annual output of gari (tonnes)	1100	1100	3300	1100	3300	
Labour force	234	45	135	28	88	
Investment Costs						
Buildings[2]	154440	95000		185000		
Equipment[2]	5850	55000		315000		
	160290	150000		500000		3.33
Annual Production Costs						
Equipment[2]	950	5830	5830	41450	41450	
Buildings[2]	16380	10070	10070	19620	19620	
Labour	192500	61000	183000	42600	127800	
Cassava	82000	82000	250000	96000	288000	
Fuel	14400	7200	21600	30000	60000	
Packaging	12000	12000	35100	13000	39000	
Transport and distribution	3600	3600	10800	6000	12000	
	321830	181700	516400	248670	587870	
Investment/Labour (₦)	685	3334	1112	17860	6000	5.36
Investment/Output (₦/t)	145	137	46	455	162	3.32
Total cost per tonne gari (₦)	293	165	156	226	178	1.37
Labour cost per tonne gari (₦)	175	55	55	39	39	0.71
Energy cost per tonne gari (₦)	13.09	6.55	6.55	27.27	18.18	4.16

1. Number of 8-hour shifts per day.
2. Prices for intermediate and fully-mechanised factories are based on manufacturers' estimates and building costs in 1979. Annual costs obtained by discounting at 10% for the expected lifetime of fixed assets.
3. Cassava costs have risen from ₦12/tonne in 1973-74 to ₦25/tonne in 1979.

Table 31. Comparison of some non-economic implications.

Aspects	Traditional labour intensive	Post-traditional intermediate	Modern fully mechanised
Management and organisation			
Need for skilled labour	small	small	large
Maintenance requirement and source of spare parts	small (local)	moderate (local)	moderate (imported)
Reliance on infrastructure (roads, communication systems, electricity and water supplies)	small	moderate	large
Organisational complexity	large	moderate	large
Socio-cultural			
Role of male and female workers	Women are processors with independent income from processing	Women may be employed as processors. Men operate and maintain machinery	Women employed for manual tasks. Men are processors and operators
Quality of the employment offered	low (unskilled)	moderate or low	moderate and high (skilled)
Ecological			
Geographical concentration of waste production	low	low	high
Need for waste water treatment	none or low	none or low	high
Possibilities for waste utilisation	peel as animal feed	peel as animal feed	peel as animal feed only after drying
Energy requirements (de-forestation)	firewood	firewood, coal/oil	oil/electricity

observed but there are several strong reasons for the continuation of traditional processing in the immediate future (Williams, 1978).
(1) The high initial investment needed for equipment cannot be made by the individuals or small groups normally producing gari by traditional methods.
(2) Mechanised production would mean a loss of employment and independent income for many women involved in labour-intensive gari processing.
(3) Small farmers have little opportunity to sell cassava to large-scale factories which obtain raw materials from plantations. In an area where mechanised processing is introduced the establishment of new plantations could lead to the displacement of local farmers.

In Table 36 a number of important considerations for the choice between different gari technologies are summarized. In this evaluation only the costs and not the benefits of selling gari have been considered. The reason for this is that at present in Nigeria the price of gari (and other foods) is so high (1-1.5 Naira per kg of gari) that its manufacture is highly profitable at any scale or by any production system. The factors limiting mechanised gari production are the lack of capital, knowledge, and experienced entrepreneurs. An industry in Nigeria devoted to the development and manufacture of efficient gari processing equipment could also help to eliminate the shortage of this staple food.

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13 Maize

13.1 MAIZE PRODUCTION

Maize (*Zea mays* L.) is an indigenous cereal crop of the Americas, where it has been an important staple food for centuries. Since the 16th century it has been spread throughout the world so that now maize is one of the three main cereal crops, the others being wheat and rice. Each of them accounts for roughly one quarter of the increasing total world cereal production (Table 32). Table 33 shows that one single country, the USA, provides almost half of the total world production. Maize is the most important staple food in a number of countries in Africa and Central America, while in Asia, South America and Southern Europe it makes a large contribution to the diet. Nevertheless, it is estimated that approximately two-thirds of the total world production is used for animal feed.

13.1.1 Cultivation

Maize is grown in the warmer parts of temperate regions, in the humid sub-tropics and the savanna areas of the tropics. Because there exists a large number of cultivars with different maturity periods, maize can be grown under a range of climatic conditions. Maize is grown for grain in latitudes from 50° North to 40° South and from sea level to 3300 m altitude (e.g. in the Andes and Mexico). In areas outside these limits, it may still be grown for green feed. Only in the colder parts of temperate areas, tropical rain forests and semi-arid or arid regions of the world other staple crops perform better.

When grown under favourable conditions, maize has a higher potential yield than other cereal crops, especially sorghum and millets, the indigenous cereals of Africa. Although root crops, bananas and plantains normally yield more in tonnes per hectare, only cassava and bananas exceed maize in energy yield per unit area of unirrigated land (see Table 18).

Immature cobs may serve as a pre-harvest hunger-breaking staple. The mature plants can be left in the field as long as weather conditions, insects

Table 32. World production of main staple crops in million metric tonnes. (from FAO Production Yearbooks 1975-1978, published in 1976-1979)

	1970	1975	1978
Total cereal grain production	1214	1362	1581
Wheat	319	355	442
Rice	309	360	376
Maize	262	324	363
Total rootcrop production	563	553	523
Potatoes, Irish	312	286	273

Table 33. Production of maize by geographical regions and selected countries, in million metric tonnes. (from FAO Production Yearbooks)

	1961-65 average	1971-75 average	1978
World	216.7	308.3	361.9
North and Central America	105.8	152.6	196.2
Canada	1.1	2.9	4.2
Mexico	7.4	8.8	9.6
United States	95.6	138.7	179.9
South America	17.8	27.3	26.9
Argentina	5.0	8.6	9.7
Brazil	10.1	15.4	13.7
Asia	37.9	50.2	54.8
China	22.8	30.6	34.0
India	4.6	5.8	5.5
Indonesia	2.8	3.1	2.5
Philippines	1.3	2.7	3.2
Thailand	0.8	2.3	3.3
U.S.S.R.	13.1	10.3	9.0
Europe	25.7	44.3	48.3
Bulgaria	1.6	2.3	3.4
France	9.0	9.8	9.3
Hungary	3.4	5.9	6.2
Italy	3.6	4.9	6.0
Romania	5.9	8.3	10.2
Spain	1.1	2.0	1.9
Yugoslavia	5.6	8.2	7.4
Africa	16.2	23.3	26.4
Egypt	1.9	2.5	2.8
Kenya	1.2	1.5	1.8
Nigeria	0.8	1.0	1.4
South Africa, Rep. of	5.2	8.5	9.9
Oceania	0.2	0.3	0.3

and other pests allow. As maize kernels do not separate from the ear when ripe, the grain does not fall to the ground. The husk provides protection against birds and rain.

13.1.2 Harvesting and shelling

The maize kernel is physiologically mature when the grain contains about 35% (w/w) moisture (i.e. it accumulates no more dry matter). If harvesting is done by hand in the dry season, the crop is often left in the field to dry until the moisture content of the grain lies between 20 and 15%. Mechanical harvesting is usually done when the grain is softer to avoid physical damage. The optimum moisture content in this case is between 25 and 28%. The husks are removed from the ears during harvesting or later at the farm.

The shelling of maize (the removal of the seeds from the cobs) on many small farms is still done by hand or by beating the cobs with a stick. Simple shelling devices which can be manufactured locally have been developed recently, while hand and/or pedal operated machines (output 30-125 kg/h) and powered maize shellers are commercially available (FAO, 1979). The outputs from powered shellers range from 150 to 300 kg/h for a 1 hp machine to 700 to 1700 kg/h for 5 hp machines (1 hp = 740 W). Larger shellers, driven by the power take-off of a tractor yield about 2500 kg/h. 100 tonnes of dehusked cobs yield 70 to 80 tonnes of maize kernels.

Agricultural yields of maize, usually given as the shelled kernel, vary considerably due to the conditions under which the crop is grown in different areas of the world. They range from about 7 t/ha in USA corn belt states to less than 1 t/ha in some countries of Africa and Asia. Yields are sometimes quoted in bushels or in bags. The bushel weight of maize is about 25.5 kg (56 lbs) and the standard bag weight 90 kg (200 lbs).

13.1.3 Drying and storage

Proper storage of maize is a major problem in various areas of the world, not only on the farm but also at the more central level of storage by traders, marketing boards and the maize processing industry. Storage losses at both stages are often excessive. Although methods exist for storing maize for virtually any length of time, economic, social and political factors influence the selection of the storage technique in any situation. The method of storage is generally a compromise between minimum cost and acceptable quality over the required period.

In a survey of post-harvest losses in developing countries the FAO (1977) reported average maize losses from 9.6 to 20.2% occurring mainly during storage. The actual extent of losses during storage are difficult to calculate because the loss estimates published are not based on standard determination methods (NAS, 1978). Maize shows specific problems of loss estimation as it can be stored either shelled or on the cob. The causes of losses during storage of maize are:

- biological deterioration due to insects, mites, rodents, birds, fungi and bacteria;
- poor warehouse practice and/or less suitable equipment due to a lack of knowledge, interest or finance;
- theft;
- biochemical and chemical changes in the grain, mainly caused by respiration of the grain.

The reduction of maize storage losses can be achieved by measures commonly applied to the storage of other cereals (see Hall (1970) for an introduction to this subject). A survey of existing traditional and improved storage practices for small farms has been published by the FAO (1979) and manuals on this subject for extension workers are also available (Lindblad & Druben, 1976; Dichter, 1978).

Damage during harvesting and shelling, moisture content of the kernel and temperature play an important role during storage, because the physiological activities of micro-organisms, insects and maize kernels depend on these factors. The maximum moisture content depends on the temperature and the anticipated storage period. The limits usually recommended are 13.0 to 13.5% for 1 year storage and 10 to 11% for 5 year storage of shelled maize (Brooker et al., 1974; Hall, 1970). If maize is stored in the shade at ambient temperature, the observation of these limits should ensure that the physiological activity of bacteria, fungi and the grain are reduced to a minimum. Other measures, such as the application of insecticides, fumigants or airtight storage have to be taken against insects and mites.

Although initial drying is usually achieved by leaving the maize

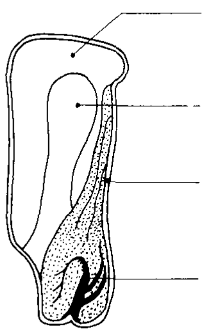

Fig. 35. Structure of maize kernel.

standing in the field, problems can arise which force the owner to consider other drying methods:

- Weather conditions may reduce the rate of drying to such an extent that fungi can grow on the grain. This often happens in the humid tropics or when new farming methods (irrigation, fast maturing cultivars) force farmers to harvest in the rainy season.
- When the weather conditions are favourable, losses in the field to insects, rodents, birds, other animals or thieves may become unacceptably high.

Technical information on driers with different degrees of sophistication used to preserve grain, can be obtained from Brooker et al. (1974). Driers (including solar driers) suitable for small farmers have been described by GTZ (1979), BRI (1975), Lindblad & Druben (1976) and FAO (1979).

13.2 USES

Figure 36 gives an overview of the ways in which maize is utilized. Although maize is mainly grown for its grain, it is also grown for utilization of the whole plant as animal feed or green manure.

FAO data (Table 34) show that:

- In many developing countries where little wheat or rice is produced, almost all maize is used for human consumption.
- In many industrialized countries maize is mainly used for animal feed.
- The amount of maize used for industrial purposes is relatively small.
- Assuming that less than 1% is required for seed, a considerable amount of maize is lost through waste. These losses occur mainly, but not exclusively, in developing countries.

The discussion on maize processing will be restricted here to dry milling because in the developing countries the floury products obtained are important staple foods (Fig. 36), while production of starch is relatively less important and wet milling is largely done by traditional methods only.

For a better understanding of the effects of processing, the structure and composition of the kernel must be known. Figure 35 shows the structure of a maize kernel. The chemical composition of a maize kernel may vary with growing conditions (soil, climate etc.) and cultivar. The most common cultivars grown for human food and animal feed are of the dent and flint type. More types are being bred, such as "amylomaize" in which the amylose fraction of starch goes up to 80%, "opaque-2" with higher lysine and tryptophan content and cultivars with a higher oil content.

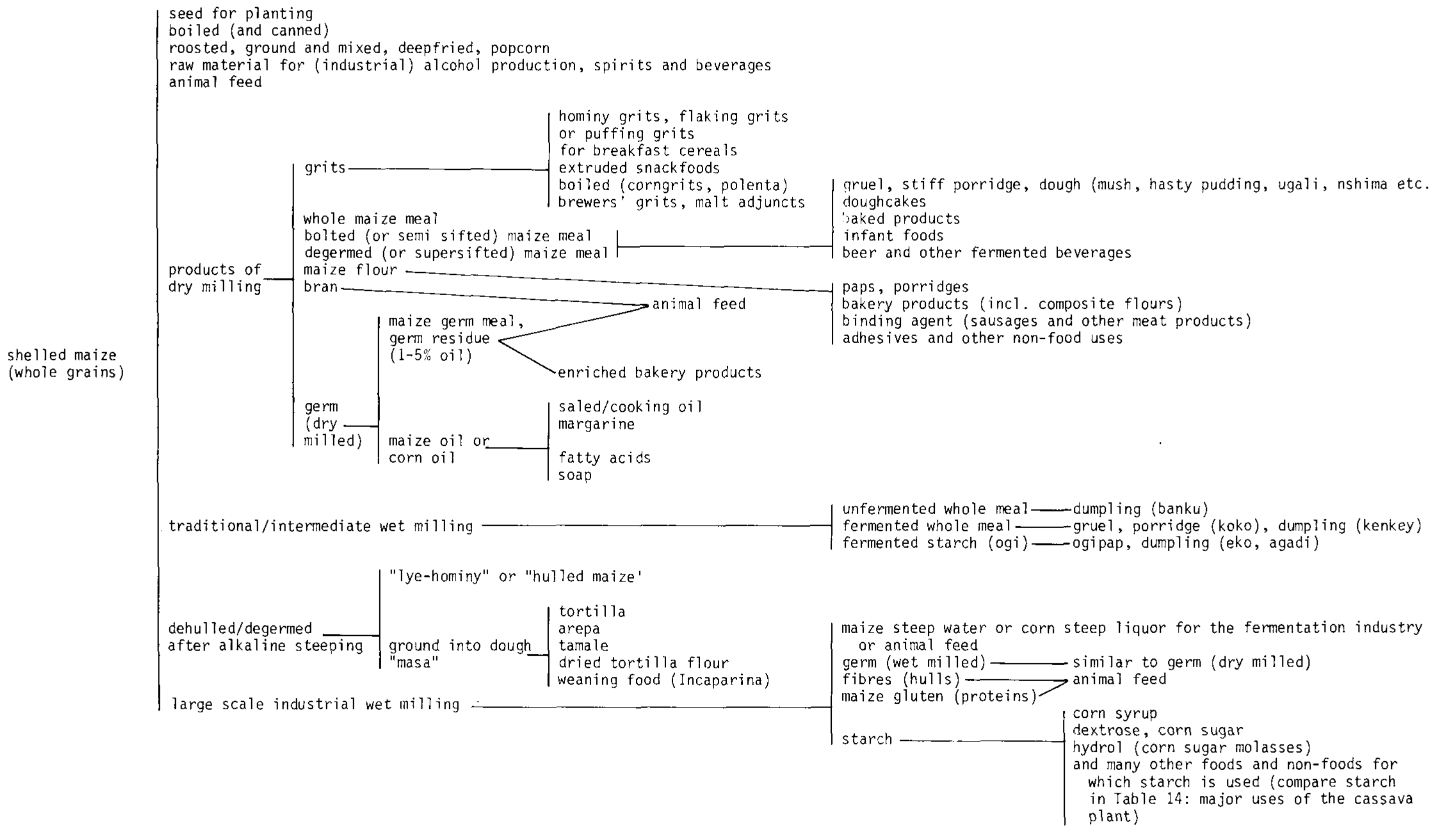

Fig. 36. Uses of shelled maize.

Table 34. Estimated utilization of maize, selected countries -1972-1974 average, in thousand metric tonnes. (from FAO, unpublished studies quoted in P.S.R. Kosters, 1980)

	Food	Feed	Industrial use	Seed/ Waste	Total
Industrialized countries					
Australia	52	96	-	1	149
Canada	723	2647	73	122	3565
France	226	5019	405	112	5762
Germany, Dem.Rep.	-	1082	321	48	1162
Germany, Fed.Rep.	719	2197	56	71	3043
Italy	275	8665	617	90	9647
Japan	1111	5969	164	7	7272
Netherlands	220	2200	-	20	2240
Poland	-	574	57	6	637
Romania	1671	6134	87	367	8259
South Africa, Rep.	2986	2399	117	527	6019
United Kingdom	798	1697	871	-	3366
United States	6102	98878	5157	440	110577
U.S.S.R.	89	11333	361	2491	14274
Developing countries					
Argentina	193	3334	-	538	4065
Colombia	729	86	5	54	874
Egypt	1361	1025	81	147	2614
India	4445	144	-	1264	5854
Indonesia	2380	61	-	132	2573
Kenya	1264	16	-	168	1448
Malawi	933	64	-	192	1189
Mexico	6359	1310	1359	430	9458
Philippines	1785	361	70	93	2309
Tanzania	709	20	-	65	794
Turkey	380	587	89	54	1110
Zambia	633	43	73	225	974

Table 35. Average composition of whole maize kernel and hand-dissected fractions (percentage by weight on moisture-free basis). (from Earle et al., 1946 as quoted by Inglett, 1970)

	Kernel	Starch	Protein	Lipid	Sugar	Ash
Whole grain	-	71.5	10.3	4.8	2.0	1.4
Endosperm	82.3	86.4	9.4	0.8	0.6	0.3
Germ	11.5	8.2	18.8	34.5	10.8	10.1
Bran	5.3	7.3	3.7	1.0	0.3	0.8
Tip cap	0.8	5.3	9.1	3.8	1.6	1.6

Flint maize has a hard kernel with rounded ends. The appearance of the grain is due to the large amount of hard or horny (corneous) endosperm along the sides and top of the kernel and small quantity of soft, floury endosperm in the centre. It is mainly grown in Europe, Asia, Central and South America and parts of tropical Africa. Dent maize has a larger proportion of floury endosperm than flint maize. It extends from the top of the kernel to the layer of horny endosperm at its sides and causes the characteristic dent in the grain due to shrinkage of the soft endosperm on drying. The wedge shaped grains are generally larger than flint maize. It is the principal grain of the corn belt in the USA and Northern Mexico.

The main component of mature maize is starch (Table 35). It is found in the endosperm of the kernel, mainly in the soft endosperm. The starch granules of normal maize contain about 25% amylose and 75% amylopectin. Although the protein content of maize is similar to that of other cereals, the quality of the protein with reference to human nutrition is in comparison poor. Chemical analysis and biological evaluation show that most cereals have medium quality protein with one limiting amino acid, lysine. Maize is deficient in both lysine and tryptophan (FAO/WHO, 1973). During processing parts of the kernel may be discarded. If, as in degerming the germ, bran and tip cap (together 18% of the whole grain) are completely removed, not only is 25% of the total protein removed, but the quality of the remaining protein is poorer because relatively large amounts of lysine and tryptophan are concentrated in the germ. The opaque-2 variety has twice the normal amount of lysine and tryptophan in the endosperm. Unlike wheat and rye, maize does not contain the protein gluten and cannot be used for baking leavened bread without special additives. The maize proteins in "maize gluten", a by-product of wet milling, have different properties and are predominantly used in animal feeds.

Besides starch and proteins, maize contains minor amounts of B-vitamins like niacin, thiamin and riboflavin. The niacin and useful amounts of thiamin and riboflavin are located mainly in the germ and aleuron layer, the layer of endosperm cells bordering on the bran. During removal of the bran part of the aleuron layer is often lost, and with it some vitamins. Niacin (including both nicotinic acid and nicotinamide) occurs in maize mostly as the bound form, niacytin, which cannot be absorbed by man. The vitamin can be liberated from niacytin by treatment with alkali. This is traditionally performed by steeping maize in lime water, as done in Mexico and other parts of Latin America. In industrial maize processing such treatment is only applied for the production of "lyehominy" and tortilla flour.

In freshly harvested maize nearly 85% of the lipids, mainly triglycerides, are found in the germ. The germs are a commercial source of oil, known as maize or corn oil. During storage oil migrates slowly from the germ to the endosperm. Although storage periods of about 6 months have been found to cause little oil migration, after 18 months the endosperm may contain up to 3 or 4 times more oil than it did initially. This is of special importance for dry milling because the yield and oil content of maize grits, meal and flour are affected by the age and quality of the grain.

As it is evident that processing has considerable influence on product quality and properties, it is important to use a clear terminology for the various products. The terms meal and flour have often a synonymous meaning. In this study the term 'meal' is used for the products 'whole meal', 'bolted meal', and 'degermed meal', and the term 'flour' for products with a finer particle size. 'Gristing' applies only to the production of whole meal. Whole meal, bolted meal and degermed meal are obtained by removing different amounts of bran and germ during milling. This controls the chemical composition and physical properties of the products. If product standards exist

Table 36. USA standards for maize products. (from U.S. Food and Drug Administration; Code of Federal Regulations, Title 21, part 15, as quoted in Inglett, 1970)

Corn product	Fat[1]	Fibre[1]	Moisture	Sieve tests (through)		
Corn meal				No.12	No.25	No.72XXX
	May differ $\leq$ 0.3% from cleaned corn	$\geq$ 1.2% and not more than cleaned corn	$\leq$ 15%	$\geq$ 95%	$\geq$ 45%	$\leq$ 35%
Bolted corn meal				No.20	No.25	No.72XXX
	$\geq$ 2.25% and $\leq$ 0.3% greater than the fat of cleaned corn	< 1.2%	$\leq$ 15%	$\geq$ 95%	$\geq$ 45%	$\leq$ 25%
Degerminated corn meal				No.20	No.25	No.72XXX
	< 2.25%	$\leq$ 1.2%	$\leq$ 15%	$\geq$ 95%	$\geq$ 45%	$\leq$ 25%
Corn grits				No.10	No.25	
	$\leq$ 2.25%	$\leq$ 1.2%		$\geq$ 95%	$\leq$ 20%	
Corn flour					No.50	No.70[2]
	May not exceed that of cleaned corn		$\leq$ 15%		$\geq$ 98%	$\geq$ 50%

1. Moisture free basis.
2. After washing with petroleum ether.

- which is not the case in many countries - they are generally limited to fat content, fibre content and particle size. An example is given in Table 36. In most countries the product quality is determined by competition between milling companies.

Apart from the variation in nutritive value, the difference in composition of whole meal, bolted meal and degermed meal affects storability, marketability and final use. Whole maize meal (also known as whole meal flour) has a low shelf stability as the complete kernel is converted into meal. Oil and lipases are released from the germ, and are responsible for the quick development of hydrolytic rancidity. After grinding, the components of the meal are more exposed to oxygen than in the intact kernel, so oxidative rancidity catalysed by lipoxidases from the germ will develop readily during storage.

Whole maize meal will become rancid within one to five weeks. This restricts its sale to:
- markets close to the processing unit;
- markets served by an efficient transport system;
- markets with a high turnover rate.

Whole meal is not a suitable ingredient for products requiring a long shelf life such as infant foods and industrially prepared baking mixes.

Almost all of the germ and bran are removed during the manufacture of degermed (degerminated, supersifted or grade I) maize meal. Under carefully controlled conditions (low moisture content, low temperature, low humidity and low oxygen concentration in the surrounding atmosphere) it may be stored for 18 to 24 months. In commercial practice this is not attained however the shelf life is much longer than that of whole meal, allowing more time for storage and distribution. Degermed meal often has a fine particle size which is appreciated by many consumers. It has a lower nutritive value, however, and is generally more expensive than whole maize meal. In storability, marketability and final use bolted meal falls between whole and degermed meal. Maize flour or corn flour, characterised by a particle size smaller than meal, is hardly known outside the USA as a separate product but is usually included in the meal. In the UK 'corn flour' refers to wet milled corn starch.

13.3 WORLD MARKET

The tables on production (Table 33) and utilisation (Table 34) reflect the supply and demand for maize in the world. The difference between food use in developing countries and feed use in industrialised countries is also illustrated by the way maize production is organised in these countries. In most industrialised countries a small number of people produce maize on farms using high energy inputs and virtually all of the crop is commercially marketed. The remainder is used to feed livestock on the farm. In many developing countries maize production is split between two sectors. On small farms the crop is grown primarily for subsistence requirements with any small surpluses being sold locally. Larger farms produce almost all of the maize for the commercial market. It may be sold for domestic use (to feed people in urban centres or plantation areas) or international trade.

Although the amount of maize entering international trade is only a small fraction of the world production, it has more than doubled in the last decade (Table 37). Maize exports mainly supply the animal feed industries in countries which do not grow sufficient raw material for this purpose (e.g. Japan, Netherlands, Fed. Rep. of Germany, UK). Developing countries import maize to supplement domestic shortages of cereals. This quantity rose from 11% of the total international maize import trade in 1970 to 19% in 1978.

Table 37. International trade in maize, in thousand tonnes. (from FAO Trade Yearbooks)

	Imports				Exports			
	1970	1975	1978	1981	1970	1975	1978	1981
World	28981	51621	67492	79370	29432	51285	68401	78930
Developed countries	25414	42986	52679	58783	20613	43388	59684	66702
Developing countries	3568	8635	14813	20587	8818	7897	8717	12228
USA	84	45	51	30	14402	33503	50094	54856

The price of maize in the world market is determined by the balance of surplus USA production and demand for cereals for animal feed or to overcome shortages in large countries (e.g. the USSR). The price paid for maize within countries may differ from the world market price for political reasons. Nearly all of the international trade is in dry unprocessed maize kernels. The kernels are more easily transported and handled in bulk than flours or other processed maize products. Moreover distributors and processors in importing countries like the milling to be done locally so that they have closer control over the specification and quality of the end products. Various studies have been published on the maize trade within developing countries, particularly in Africa (Miracle, 1966; Jones, 1972; Mwamufiya & Fitch, 1976; IDRC, 1976). To quote from IDRC (1976):
'In the traditional post-harvest systems of most developing countries, grain is purchased, stored, transported, processed and sold by numerous speculators on its way from the farmers to the consumers. This results in higher costs to consumers and in less money being available to the farmer. Consequently, there is a reduced incentive for the farmer to produce more grain than he requires for his subsistence. Furthermore, improper grain handling and inadequate storage facilities contribute to high losses of both unprocessed and processed grain as a result of insect infestation, microbial contamination, dirt and spillage'.

As both farmers and consumers are interested in an efficient flow of harvested grain, the governments of various developing countries, especially in Africa, have decided to promote or even impose marketing co-operatives or marketing boards. These organisations are supposed to streamline the flow of grain by buying directly from farmers and selling to the processing industries. They provide large well maintained buffer stores which reduce storage losses and moderate price fluctuations throughout the year. They should also safeguard the interests of the small farmer. These organisations have the advantage for grain processing industries, whether independent or owned by the marketing organisation, that they do not need a large purchasing organisation or large storage capacities for their raw material. This is in contrast to the situation in industrialised countries, where farmers own sophisticated storage systems, and the processing industry which buys raw materials from farmers must carry stocks equal to several months' production requirement.

13.4 AVAILABLE TECHNOLOGIES FOR DRY MILLING

Milling is an ancient way of transforming cereals into a form which is convenient, attractive and easily digestible for humans. Mortars and pestles

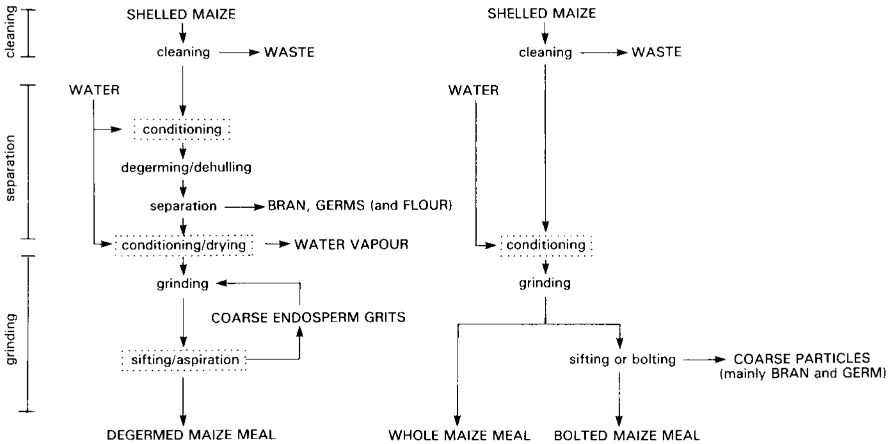

Fig. 37. Basic processes for the production of degermed, whole and bolted maize meals by dry milling.

have been in use for 10000 years and the rotating stone mill which started its development about 2000 years ago has not yet been phased out, although very few remain in industrialised countries.

Maize milling technology other than home pounding or stone grinding has only been in development for about a hundred years. The equipment has evolved from roller mills originally designed for wheat. The first degermer especially developed for maize became available commercially in 1906 and the development of hammermills started at about the same time.

In developing countries maize processing used to be done at home. Now, with increasing urbanisation, division of labour and specialisation in the agricultural sector, more maize has to be processed at an industrial scale or by labour-saving techniques. Several different processing technologies have been introduced, however not all of them give satisfactory results. Methods of dry milling to obtain maize meal as a staple food will be considered in detail. Although in dry milling some water may be added to the kernels to achieve optimal yields (final moisture content lies between 10 and 25% (w/w), the gross appearance of the grain and flour will remain dry. Much more water is added in wet milling (grain moisture content about 40%).

13.4.1 Basic process

Dry milling of maize can be divided into the following stages; cleaning, an optional germ and bran separation stage, and a grinding stage with optional classification (Figure 37). For all levels of technology the process involves the operations of separation, conditioning and size reduction.

Size reduction operations, which include grinding, degerming and dehulling are energy intensive. The feedstock (the material to be ground) has to be deformed to a certain degree before breakage occurs. The energy required for the deformation which is applied by shear forces, pressure or impact, is released as heat at the moment of breakage. As all degerming, dehulling and grinding operations are subject to these physical principles, the selection of one technology is mainly determined by the availability of energy and capital. In cases where little capital is available and human power has to be used, the grinding equipment, such as mortar and pestle, millstones and disc attrition mills, is based on pressure or shear forces. Size reduction by impact as in hammermills requires high velocities which can only be attained by combustion engines or electric motors. These become economically viable with low energy costs and large markets.

Grinding is in general a random process. Grains are broken into pieces with little control over particle size. Because of the structure of the cereal grain, however, breakage may take place in a more selective way, the brittle and floury endosperms generally breaking into smaller pieces than the comparatively tough bran and germ. Conditioning is used to increase the difference in texture. Water added to the kernel is absorbed first by the branny outer layer. The germ also absorbs moisture more quickly than the endosperm. After conditioning the bran and germ should be pliable and resilient but the endosperm should remain hard. As degermed meal has better storage and marketing properties size reduction equipment has been introduced which removes the germ and bran from the kernel without causing much breakage of the endosperm.

Before further milling, the germ and bran are removed by sieving and aspiration. Extra equipment, energy and labour are required so the processing costs for degermed meal are relatively high. Apart from material removed at the cleaning stage, the separated part, generally called bran, consists of the actual bran (or hull) and tip cap and may include germs and some endosperm. The germs may be recovered separately because of their valuable oil and protein content.

The efficiency of the size reduction and separation processes will determine the yield of end product. Extraction rate is the term commonly used to relate the amount of flour, meal and grits to the quantity of grain (precentage extraction rate = mass of flour, meal and grits/mass of original grain x 100). The extraction rate should be corrected for differences in moisture content between the final product and the feedstock. The type of meal (degermed, bolted or whole) clearly controls the extraction rate. A loss of material may occur by spillage or by the escape of fine flour particles after milling. The heat generated during grinding will increase the moisture lost by evaporation.

Three levels of technology will be discussed:

(1) Household milling, in which both raw material and equipment are the property of the household and the maize is processed for private consumption.

(2) Service or custom milling, in which the mill is an enterprise without stocks and serves the customers by milling their grain in exchange for payment.

(3) Merchant milling, in which the mill purchases its raw material, processes and markets its products, and carries stocks for this purpose.

13.4.2 Household milling

Examples of traditional dry milling of degermed/dehulled maize meal have been described for East Africa (Schalge, 1968) and West Africa (Muller, 1970). As these methods do not differ in principle, the flow sheet (Figure 38) applies to both. The grain is cleaned by winnowing and sorting. Winnowing is carried out by throwing the grains from a flat basket, mat, dish or tray into the air to fan out light particles, or by dropping the grain and allowing the wind to blow the light material away. Particles such as stones, pieces of cobs, infested maize kernels, and seeds other than maize are removed by hand. Conditioning of the grain may vary from a 24 hour soak to the addition of water to the mortar just before pounding. The degerming/dehulling operation is done with a wooden mortar (height about 65 cm, diameter about 30 cm) and

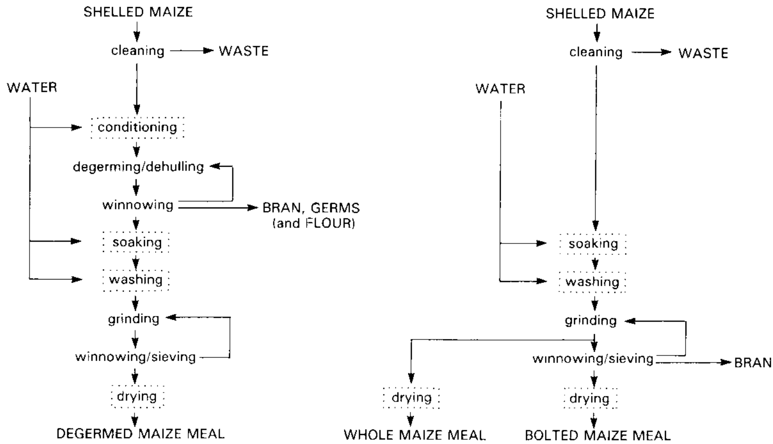

Fig. 38. Flow sheets for dry milling maize in the household. Dotted means: optional operation.

pestle (length about 120 cm, diameter about 6 cm, weight about 3 kg) after the addition of water (about 250 ml per batch of 2-3 kg). Germs and hulls are separated by winnowing. According to Schlage (1968) the pounding and winnowing operation for maize has to be repeated three or four times before most germs and hulls are removed. He reported that the first pounding operation lasts 15 minutes. Germs and hulls are used as chicken feed or as an ingredient in traditional brewing.

Before grinding the maize grits are sometimes soaked (for 3 or 4 days) and washed. Grinding is done by pounding grits in the mortar for about 20 minutes. The bigger particles are separated by winnowing or sieving, and may be returned to the mortar for further pounding or ground on a saddle stone grinder. This consists of a flat, slightly inclined stone baseplate, over which a stone roller held in both hands is rubbed. A dish or mat is placed at the lower end of the baseplate to collect the fine material. The maize meal from both operations is combined and dried in the sun if it is to be stored for more than one day. Schlage (1968) reports an extraction rate of 55.5% for this traditionally degermed meal. In Latin America, whole maize whether soaked or dry is traditionally ground on a saddle stone known as a 'metate'. If dehulling is not applied, grinding in a mortar or on a saddle stone will result in whole meal with a rater irregular particle size. Winnowing or sieving is probably performed and the large pieces of grain are returned for regrinding, while the coarsest pieces of bran may be discarded or used as chicken feed (O'Kelly, 1973, p. 119).

The traditional milling process is both time consuming and labour intensive. As the pounding or grinding operation is particularly heavy there have been many attempts to provide equipment which uses human effort in a more efficient way. The oldest development is the quern, which consists of a hand driven convex upper stone which rotates about a spindle set in the concave lower stone. Today cylindrical stone mills and plate or disc attrition mills are well established. Recently a bicycle or pedal driven hammer mill has been developed (Pinson, 1979).

The output of most grinding equipment is low, ranging from 1 to 3 kg/h for mortar and pestle or saddle stone to 4 to 12 kg/h with more efficient mills, depending on the quality and fineness of the meal required. CCT (1980) reported that although the throughput of various imported plate mills reached the figure of 16-20 kg/h given by the manufacturers for wheat, millet and sorghum, the output of ground maize was much lower. The maize had to be ground two or three times before obtaining the fineness required by local consumers.

Using the pedal-driven grain mill, maize must also be ground two or three times, resulting in only 1 kg of meal of the fineness required every 2-4 hours (CCT, 1980). Some experiments with this meal at the Royal Tropical Institute, Amsterdam, have shown that when pedalling at 1 per second (60 rpm) an output of 6 kg/h can be obtained but the meal contains a lot of coarse grits.

Household milling is in most societies the responsibility of women. If used only by the owners, the utilisation of the equipment is limited to a few hours or less daily, depending on the amount of meal required (IDRC, 1976). Most of the equipment is also used for grinding or crushing other foods such as cereals, groundnuts, grain legumes and dried chunks of cassava root. Pounding can be speeded up if two or three women with pestles are working on one mortar. With other grinding equipment the througput can be increased if one person supplies the power while the other regulates the feed. Some plate mills are provided with handles at both ends of the shaft, but the required co-ordination between the two operators is not always understood (CCT, 1980).

13.4.3 Custom or service milling

Despite improvements, grinding and degerming/dehulling remain the bottleneck in the traditional milling process. With the use of other sources of energy the capacity of existing equipment can be more fully exploited and mills with higher outputs become possible. Initially domestic animals, waterwheels or windmills were used but now diesel engines and electric motors are available for driving disc and hammer mills. These technologies require a higher capital investment and have higher operating costs (animal fodder, maintenance of a dam, furrow and driving train, or the costs of fuel or electricity). The necessary financial outlay can only be justified if the throughput is higher than that from a single household. Enterprises such as custom of service mills process customers' maize for a sum of money or the payment of a regular membership fee. Although normally mechanised, reports of hand operated disc mills in the service sector have been made (O'Kelly, 1973; Stewart, 1978; CCT, 1980).

In service milling the cereal remains the property of the customer but the grinding and sometimes also the degerming/dehulling operation is performed by a separate organisation, either a private enterprise or a co-operative. As virtually no meal remains in the equipment after use customers receive the maximum amount of meal from their maize. In general, the customer must transport and pack the maize and the milled product(s). The mill is not involved in the trade of raw material or milled products and carries no stocks, except that in some cases customers' maize might be stored. By providing a service to customers, the size of its market is limited by the distance which can be easily travelled by the customer with his or her load of maize. A survey in Kenya (Stewart, 1978) has shown that as transport is by foot, bicycle, or cart or donkey the maximum distance travelled to a mill in rural areas is 3 to 5 km (2 to 3 miles).

The theoretical capacity of the equipment commonly used in service mills is 10 to 200 kg/h for stone mills, 10 to 100 kg/h for disc mills and 50 to

5000 kg/h for hammer mills. The actual throughput may be much lower because of the time the machine runs empty between customers' batches. The capacity utilisation of the equipment may vary considerably depending on the number of customers, the size of the batches and the fineness of meal required. In most countries of Africa (although not in all locations) there appears to be excess capacity in the custom milling sector (Uhlig & Bhat, 1979). It has been reported that on average water-powered stone mills operate 8 to 10 hours per day in Kenya, and hammer mills 4 to 8 hours per day (Stewart, 1978; Uhlig & Bhat, 1979). Keddie & Cleghorn (1980) based their model for a hammer mill on 200 operational hours per month during the 3 month harvest season and 67 hours monthly in the remaining part of the year. In our opinion this is realistic for East Africa. Custom mills frequently grind other cereals, pulses and dried chunks of roots such as cassava. Eastman (1980) indicated that a hammer mill processing 650 to 750 kg/h requires 9 to 12 kW (12-16 hp).

Labour is required only for weighing batches to determine the milling charges, machine operation which includes filling the hopper, adjusting the mill and collecting the meal and daily cleaning and maintenance. In general the total manpower consists of a manager with a little technical experience, sometimes assisted by one or two labourers without any formal technical training.

Mill stones are usually cut out of hard types of rock, but they may be made from concrete. In some developing countries they are made locally. Hammer mills and disc mills are manufactured in several developing countries, or they may be assembled from imported components. More details of equipment are published by FAO (1979), Uhlig & Bhat (1979) and Eastmand (1980).

For part of the population of Africa (and of the south-eastern states of the USA) dry milling techniques grind maize finely enough to make it acceptable as whole or bolted meal. To increase the fineness of the whole meal, a second milling may be required with a narrower clearance (stone and disc mills) or with a finer screen (hammer mill). This brings a decrease in capacity and an increase in milling costs. In all other areas maize is dehulled/degermed before grinding, either by wet milling and sieving as in parts of West Africa, or by processing in a dehuller and subsequent dry milling.

There are not many dehullers suitable for processing maize at a small scale. Most commonly used is the 'Engelberg' type dehuller. This sturdy machine was originally designed for the conversion of paddy into milled rice in a single operation (150-400 kg/h, requiring a 12 kW (= 16 hp) combustion engine or electric motor) and is still popular in rural areas of many developing countries for dehulling paddy at village level (van Ruiten, 1979). In East Africa it is used in service mills after adjustment to the grain size for dehulling both paddy and maize. A recovery of about 58% milled rice from paddy is given by van Ruiten; we estimate a recovery for maize grits of 60%. The bran produced is not lost as most customers collect it for animal feed. Another machine is the abrasive type PRL/RIIC dehuller designed for sorghum, millet and cowpeas (Eastman, 1980) which is also suitable for dehulling maize. The original PRL dehuller is also reported as suitable (IDRC, 1976) but it is not known how effectively it removes the germ. It has been mentioned that the maize has to be soaked for 15 minutes before dehulling.

13.4.4 Merchant rolling mills

In urban areas, where most consumers are not involved in agriculture, the supply of staple foods requires a more complicated distribution system than in rural areas. Among consumers with higher incomes there will be a demand for convenience foods such as ready milled meals, because the time and energy spent on purchasing and processing grain could be more profitably spent on other activities. This provides an opportunity for milling industries to operate, purchasing grain, processing and packing it, and selling the products through wholesale and retail outlets. As the distribution of the meal takes more time than in household and service milling, preference is given to the production of degermed and bolted maize meal because of the increased shelf life of these products. The low fibre content may also be appreciated by the consumers.

A total merchant milling operation involves intake, storage, milling of maize and subsequent packing, storage, distribution and sales of the products. There are two types of mills used for merchant milling. The most commonly used is the roller mill, but recently also hammer mills have been introduced in merchant milling. In this section merchant roller milling operations at a capacity of 1 to 50 tonnes per hour will be discussed in detail. In section 13.4.5 merchant hammer milling will be shortly discussed. A comprehensive description of large scale multi-stage dry roller milling with alternative cleaning and degerming systems is given by Brekke (1970), while Uhlig & Bhat (1979) give a survey of current practices in developing countries and information on packing meal.

13.4.4.1 *Maize intake and storage*

Two methods exist for storing maize: (1) bags containing a standard weight of maize usually 90 kg stacked in a warehouse, and (2) bulk storage in silos. The choice between the two methods depends on the processing capacity of the mill, required storage capacity and how the maize is delivered to the mill.

Bag transport and storage is a labour intensive but flexible system, as bags, storage rooms and means of transport, such as flat backed lorries and railway wagons, may be used for other purposes (e.g. transport of spares, transport of milled products etc.). Labour is required for unloading vehicles, transfer, stacking and destacking of bags although occasionally a bag conveyor belt may be used. The repair of bags, cleaning and pest control in the warehouse are essential ancillary activities. The mill has to be fed continuously by a man slitting open bags over a hopper.

Bulk transport and storage is almost fully mechanised but is less flexible because grain moving equipment, silos and transport are specifically designed for handling cereals and shelled legumes. Apart from keeping silos free from dirt, infestation, clogging and heat or moisture development, labour is only required for supervising the transfer of maize from supply vehicles into the system conveying it to the silos. Maize delivered in bags can also be fed into the silos. The mill itself is usually fed automatically from the silos by electrically driven conveying equipment (bucket elevators, augers or screw conveyors, belts).

A regular and continuous feed to the mill is most important, as any interruption at this point would immediately affect the throughput of any subsequent operation. The storage capacity should equal the processing capacity over the longest period over which no deliveries of maize are expected. In merchant mills this may vary from 5 days to several months, depending on the prevailing marketing system. The smaller the storage capacity, the less vulnerable the mill is to infestation and other storage associated problems. The IDRC recommends separate storage facilities outside the mill premises, if it is necessary to store more than a 5-day requirement of grains (Eastman, 1980).

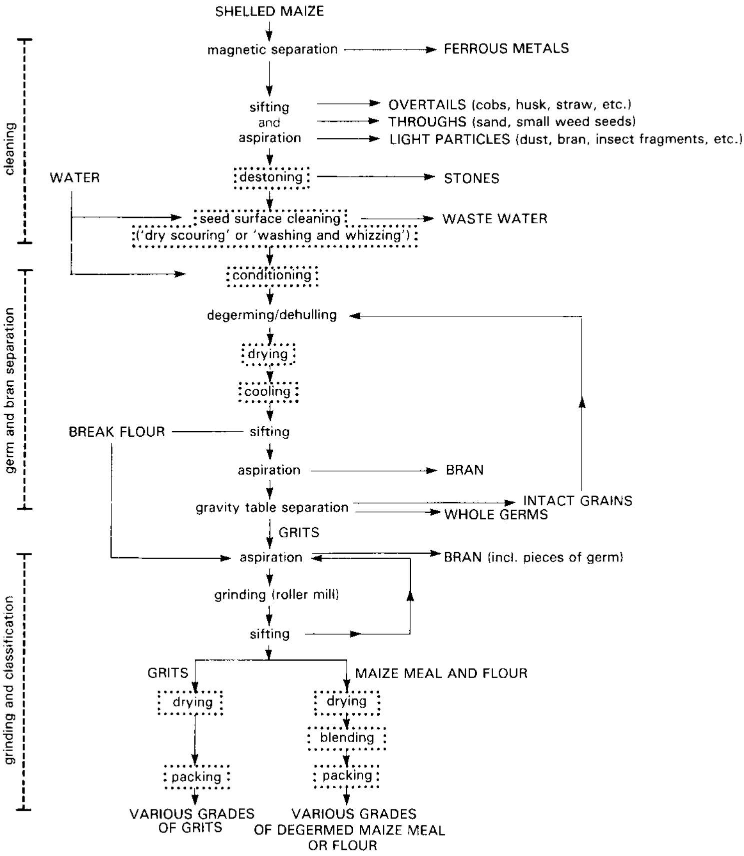

Fig. 39. Flow sheet of multistage roller milling of maize with dehulling/ degerming. Dotted means: optional operation.

13.4.4.2 *Milling process*

In a merchant roller mill the stages of cleaning, germ and bran separation, grinding and classification can be recognised. The flow sheet in Figure 39 shows details of each of the main stages. Variations especially in the methods of degerming and the process capacity are common.

The basic equipment for cleaning maize is a permanent magnet to remove any tramp iron and a grain cleaner or milling separator, which removes most other foreign material by sieving and aspiration. Further cleaning is seldom required due to the large size and smooth surface of the maize kernel. There are a large variety of grain cleaning systems including the conventional dry 'scouring' method for the removal of stones and dirt adhering to the maize and the more radical wet 'washing and whizzing' treatment. The selection of a suitable cleaning system will depend on the costs of the equipment, the efficiency of the dirt removal and the desired moisture content of the maize.

Cleaning with 'washer, stoner and whizzer' will increase the moisture content by about 2%.

A germless and branless flour can be obtained from grains by 'reduction milling' in a multi-stage roller milling system. For wheat this system has been gradually developed since about 1830. Multi-stage roller milling of maize is a much later development not only because urban areas where maize is an important staple (e.g. South Eastern USA) have developed more recently, but also because of the shape and structure of the maize kernel. The germ fraction of maize represents 12% of the grain weight in comparison to 2.5% of wheat, while the proportion of bran is only 6% compared to 12.5% in wheat. An effective recovery of whole germs (containing 35% oil) at an early stage of the milling process is required to ensure meal with a low oil content (about 1%). With a multi-stage roller milling technique this can be achieved either by a very comprehensive system of roller mills, sifters aspirators and purifiers, or by special maize degerming equipment. Simple roller milling systems without degerming equipment produce a type of bolted maize meal. Since the beginning of this century several types of degermers have become available although most milling equipment manufacturers make only one type. They can be divided into two groups by their action and conditioning requirements.

The 'wet degermers' include the Beall degermer, Bühler's adapted scourer, and the roller mill if used for this purpose. Their action is based on shear forces. Conditioning of the maize may vary from a 15 minute soak to a period of 6 hours in which the moisture content is gradually increased. A final moisture content of 14 to 16% (w/w) is usual, but in special cases 18 to 27% may be required for the Beall degermer. The advantage of wet degerming is that large, low fat grits of controlled granularity can be obtained. This is important in the production of brewers' grits and corn flaking grits. Using the Beall degermer a high recovery of whole germs and of grits with a fat content of about 0.5% (w/w) is claimed. The conditioning equipment (mixing equipment, holding equipment) and additional drying and cooling equipment result in increased investment and energy costs. In comparison to other degermers the Beall model has higher investment and operating costs, due to its high power consumption.

Examples of 'dry degermers' are Simon's adapted entoleter and impact degermers from Bühler-MIAG and Ocrim. As no conditioning is required investment and energy costs are less. The optimum degerming efficiency is obtained at a moisture content between 12 and 14% (w/w). The grits have a larger variation in size, an oil content of about 1% (w/w) and possibly contain a higher percentage of breakflour than these produced by wet degerming. These disadvantages are less serious if the end product is meal. Sometimes the degerming/dehulling operation is subdivided into a wet dehulling step, and a dry step to remove remaining germs from the endosperm.

After passing through the degermer the maize stock (the term used for the product between milling stages) has to be classified. The usual system consists of a plansifter, an aspirator and a gravity table. Apart from breakflour and a mixture of equally sized germs and grits, the plansifter may produce fractions of grits of different sizes, which will be fed to the roller milling system. The gravity table usually yields three fractions: whole germs, germ-free endosperm grits and germ adherent to endosperm. The latter fraction is usually reprocessed or sent to an appropriate roller mill.

Further size reduction is done in a roller milling system which is similar to that for wheat. It consists of a set of roller mills, the number of which varies with the processing capacity and product specifications of the mill. Each roller mill operates in closed circuit with a plansifter and an aspirator. The system is designed to remove any remaining adherent germ and bran and to reduce the particle size of the grits in a controlled manner until the desired products are obtained. The roll spacing, speed differential and surface corrugation of each mill is chosen to suit the fraction to be ground. After each grinding pass the stock is classified according to size in the plansifter. Each size fraction is then sent to the appropriate stage of the downstream milling system. The aspirators remove bran particles.

If required, the milled products may be sifted, blended, dried or cooled before packing. To prevent microbial spoilage, maize meal stored at 25 °C should have a water activity below 0.6 corresponding to a moisture content of not more than 12% (w/w) (Heiss, 1968). Conveyance of stock by hand is only practical in small hammer mill systems with capacities up to 1 tonne/h. In all roller milling systems an automatic conveyor system is used. Although whole maize may be transported by augers or bucket-elevators any transfer of milled stock and by-products is carried out by a pneumatic system for hygienic reasons.

13.4.4.3 *Packaging, product storage and distribution*

The type and style of packaging is an important selling point. Both consumer tradition and the price at which alternative bags are available play an important role in the selection of the packaging material. This may in turn affect the level of mechanisation of the packing section. There are usually two distinct sizes of package; household units of 1 to 5 kg, typically 2 kg, and larger units up to 100 kg for use in institutions (schools, hospitals, restaurants, prisons, food industries) or shops which repack the meal. Conventional packaging materials for consumer units are polyethylene and single ply paper bags and for larger sizes cotton, multiply paper or gunny bags are used. Consumer units may be formed into larger units, for example by wrapping in brown paper.

There is a wide spectrum of packaging equipment from fully automated mechanised packing lines to completely manual systems. Automated systems require a high initial investment and although they run with little human supervision maintenance and repair of the equipment demands a highly skilled engineer. Simple manual systems require only storage bins, packing tables with stools, scales and trowels. The capacity of a manual system can often be greatly increased by the use of automatic dispensers that discharge an exact amount of product and machines for sewing or sealing the packages. Polyethylene bags must of course be heat-sealed. Bran and germs are usually packed in 100 kg gunny bags or transported in bulk.

Storage and dispatch of the milled product are subject to the same constraints as storage and handling of the raw material. The problems in both areas can be solved by similar solutions.

13.4.4.4 *Administration and technical services*

A merchant mill has to have proper administration and good technical services for successful operation. Small mills may not have their own workshop, but may rely on the services of outside contractors. Equipment for roller milling and spare parts almost all originate from a limited number of manufacturers in industrialised countries. Uhlig & Bhat (1979) considered the possibility that in the future a large part of the equipment could be manufactured in countries like India. This equipment would be cheaper but would have a poorer performance until experience in design and manufacture had been gained. They suggest that unless particular care is taken during milling and extra effort and expenditure is made on maintenance, the output of meal over a period of time is likely to fall below that produced from

Table 38. Typical yields of products which a large maize merchant mill with degerming and roller milling system in the USA might produce. (from O.L. Brekke, in Inglett, 1970)

Product	Yield (%)	Particle size range (mm)	Products made from primary products	
Cereal flaking grits	12	9.05-3.36		
Coarse grits	15	2.00-1.41		
Regular grits	23	1.41-0.620		
Coarse meal	3	0.620-0.297		
Dusted meal	3	0.297-0.197	fine meal	'100% meal'
Flour (= break flour)	4	<0.197		
Germs	10		maize oil	1%
Bran	26		hominy feed	35%
Shrinkage (= loss)	4			

equipment of higher quality with the same theoretical capacity.

13.4.4.5 *Capacity, yield, power and labour requirements*

To bring a maximum return on the invested capital, merchant roller mills run 24 hours per day. All equipment is driven by individual electric motors, although in some old mills central shaft and belt systems are still used. The largest and most sophisticated mills have outputs up to 50 tonnes per hour. The product spectrum and yields of such industries are given in Table 38. The yields depend on the properties of the maize to be milled, the available equipment and the way the mill is operated. Yields of small-sized grits, meal and flour can be increased by grinding down larger grits. The meal fraction may contain flour which was not separated during grinding or which was added back at a later stage. Whole meal and bolted meal can be made by adding germ and bran streams back to the degermed meal. Some mills have their own oil extraction plants. The by-products is hominy feed, a mixture of germ residues, bran, sweepings and any other maize products the mill is not able to market profitably as human food.

In developing countries mills are less complicated and have capacities only up to 10 t/h. These mills are characterised by higher extraction rates and a less diversified product spectrum. Table 39 shows a comparison of the extraction rates of merchant mills catering for different product ranges in different markets. The quality of the meal may vary because of insufficient standardisation both at national and international level. Complete and representative data are difficult to obtain.

Mills in developing countries are usually found in urban areas because of their proximity to the main markets. This ensures good road and when necessary rail connections with the depots of marketing boards, their main suppliers. A connection with the national electricity grid for the power supply can also be made. Table 40 gives the processing capacity, invested capital, power and labour requirements for model mills producing only degermed maize meal. An operation with three 8 hour shifts per day and a storage capacity of 7 days for maize and 3 days for finished products is assumed.

The differentiation of labour according to skills (as indicated in Table 40) corresponds more or less to 3 categories of activities: management

Table 39. Extraction rates and byproduct yields in various maize merchant mills, as percentage of input.

Equipment	Location	Extraction rate	Bran and germ	Milling loss	Source[2]
Roller mill with degermer	USA	60	36	4	a
Roller mill with degermer	Kenya	75 (60-90) (67-90)	23	2	b c
Roller mill	Kenya	90[1] (95-97.5)	8	2	b c
Hammer mill with dehuller/ degermer	Nigeria	80	15	5	d

1. Higer extraction rate because bolted meal is produced.
2. Sources:
a. Inglett, 1970.
b. Uhlig & Shat, 1979; data representative for 1974/75.
c. Stewart, 1978; data collected in 1969.
d. IDRC, 1976; average figures for sorghum and maize yields are given: 30% grits, 24% middlings and 26% flour.

Table 40. Investment, power and labour requirements for maize merchant mills with roller milling system including packing of meal, in bags of 2 kg each. (from Keddy & Cleghorn, 1980).

	Scale (tonnes/year imput)		
	14250	34200	34200
Technical capacity (tonnes/hour)	2	5	5
Packing system	manual	manual	automatic
Surface area (m^2)			
mill	425	700	900
storage	300	700	700
total area	1450	2800	3200
Initial investment in fixed assets (millions US $, 1976)	368	561	720
Power requirement			
installed electrical capacity (kW)	130	310	310
Labour requirement			
total	53	110	71
managers	3	4	4
skilled/administrative	12	17	17
low skilled	38	89	50

and administration; plant operation and maintenance; material handling and packing. A change in the scale of production or degree of mechanisation does not greatly influence employment in the first two categories, but jobs in the handling and packaging section are affected. Milling is often operated by a control system from a central panel. One shift miller and one assistant per shift are sufficient for capacities up to 10 t/h. Based on observations made in Keynan mills, Uhlig & Bhat (1979) concluded that 17.1 tonnes of meal could be manually packed in 2 kg bags an 8 hour shift by a group of 4 dexterous women packers. One man transferred the meal to the packing table, and 2 men were required to form bales from the bags of product.

13.4.5 Merchant hammer mills

The hammer mill has evolved since the beginning of this century mainly for the size reduction and mixing of animal feeds. While commonly operating as service mills in various developing countries for grinding maize for human consumption, hammer mills are also reported to operate on a merchant mills basis for the production of whole maize meal (Stewart, 1978). Only recently research has been done by the IDRC on producing dehulled/degermed meals from sorghum, maize, cowpeas and millets with a system based on abrasive dehulling and hammer milling (IDRC, 1976; Pilot Flour Mill Maiduguri, undated; Eastman, 1980; Forrest & Yaciuk, 1980). Based on their experience the IDRC suggests that when operating on one 8-hour shift for 250 days a year such a mill is capable of processing approximately 1400 t/y (Eastman, 1980). The actual throughput of the mill will depend on the type and variety of grain being processed. The mill would run 6 hours in each shift with the remaining 2 hours devoted to servicing equipment, keeping records and cleaning. The capacity could be doubled or trebled by introducing more shifts.

The following equipment has been recommended for this mill: (Figure 40) 5 days grain storage capacity, two bran aspirating PRL/RIIC dehullers with cyclones requiring 6 kW each, one hammer mill with fan and cyclone requiring 9 to 12 kW, one automatic weigher delivering fixed amounts of meal, one semi-

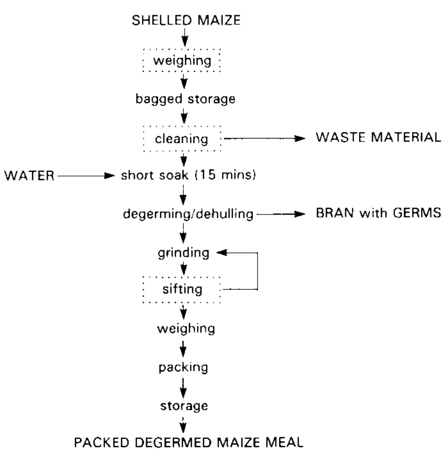

Fig. 40. Flow sheet for the production of packed degermed maize meals in a merchant hammer mill designed by I.D.R.C. Dotted means: optional operation.

automatic heat sealer for sealing 2 kg polyethylene bags, and a 5 day meal storage capacity. The system is preferably powered by two diesel engines, each of 15 to 19 kW, one for the dehullers, the other for the hammer mill and an 8 kW electric generator. The generator is required if the mill cannot rely on the public electricity supply for the heat sealer, automatic weigher and air compressor which operates the dump gate of the automatic weigher. The generator also has sufficient capacity to provide artificial lighting for the mill. The total cost of equipment, spare parts and tools was estimated in 1979 as U.S. $ 50000 ex manufacturer. It is claimed that almost all of the materials and equipment can be manufactured or purchased in most developing countries. A single storey building of 144 m^2 is suggested for the mill including storage, workshop and office accommodation.

The manpower, for one 8-hour shift, would consist of a manager, a commercial officer (book-keeper/store-keeper), a mill supervisor (miller/mechanic) and four to six unskilled labourers (Eastman, 1980). Conveyance of stock can be done by hand using containers. An auger or elevator system for degermed stock is however desirable as it reduces waste and encourages good hygiene.

It has been reported that the first experimental merchant mill of this type, located in Maiduguri, Nigeria, operated profitably producing meals of acceptable quality from locally available maize, cowpeas and sorghum (Eastman, 1980). This mill had a grain cleaner and a flour sifter which were both omitted in later experiments in Senegal, Ghana, Sudan and Botswana. The grain cleaner was not necessary because local grain was relatively free of stones and other debris. In these locations there appeared to be no demand for meal classified into different particle sizes. No specific figures could be obtained for the extraction rate and yield of maize meal (see Table 47). Bran is bagged and sold as animal feed.

13.5 EVALUATION

A statement of the aims and limitations of a project and a description of the target group are essential before starting to select the most suitable technological solution. The aims of a project can be diverse and they may be contradictory:

- to supply sufficient maize products to a population which has this cereals as a staple food (This problem requires further analysis to discover whether it is caused by a lack of production);
- to manufacture an acceptable staple food from maize;
- to alleviate the workload of all women including those involved in agriculture;
- to reduce the workload of women in the urban (non-farming) population;
- to improve the income of farmers;
- to generate employment;
- to generate capital.

The last three aims can be fulfilled by processing maize for non-staple uses (e.g. snacks) or export. In the following section such uses are not considered, as the discussion is limited to the problems of processing maize into a staple food. The evaluation is split into several categories. The relative importance of any one criterion depends on the situation under discussion.

Technical aspects

In Table 41 a summary of the physical variables of different milling technologies is given. This provides figures for evaluation of the technolo-

Table 41. Physical data representative for various dry milling technologies for maiz

	Household milling			Custom milling		
	A	B	C	D	E	F
Equipment	mortar + pestle, winnow. device	plate mill, winnow. device	plate mill	stone mill	hammer mill	hammer mill
Power[1]						
type	manual	manual	manual	water-wheel	diesel	diesel
installed cap. (HP)					20	100
Labour, tot.req.	1	1	1	1	2[2]	2[2]
Capacity						
technical (kg/h)	1 -3	4 -12	4 -12	90	600	3000
utilization (h/d)	3 -6	1 - 3	1 - 2	8	4	4
utilization (d/y)	365	365	365	312	300	312
scale of operation (t maize/y)	0.9-2.4[4]	0.7-1.7[4]	0.5-1.3[4]	225	720	3750
Output (%)						
whole meal	.	.	c.98	97	99	99
bolted meal	.	c.75	.	.	.	.
degermed meal	c.55	.	.	.	.	.
bran and germ	c.45	c.25	.	.	.	.
milling loss	c. 0[5]	c. 0[5]	c. 2[5]	3	1	1
Labour productivity (t per meal per lab per y)	0.5-1.3	0.5-1.3	0.5-1.3	215	357	1856

1. Assumed energy requirements: hammermill: 1 l diesel/180 kg maize
dehuller-hammermill system: 1 l diesel/120 kg maize
roller milling system: 1 kWh/23 kg maize
roller milling system with degermer: 1 kWh/12 kg maize
2. Employed for less than 8 hours a day, but generally for more than the effective operating hours of the mill, because of intervals between batches, clean up and maintenance.
3. Assuming packing in 2 kg paperbags. In case of manual packing in much larger units e.g. 50 kg bags, considerably less workers are required e.g. 40 workers in model L (bolted meal) increasing the labour productivity to 320 tonnes of meal per labourer per day.
4. Based on a daily consumption of 1.5 to 3.5 kg maize meal per household, i.e. 0.5 to 1.3 tonnes of meal per year.
5. No loss quantified, but assumed that all discarded or lost material in consumed by the chickens in the household or other livestock.

Sources:
Modesl A, B and C based on Stewart, 1978.
Models D, F and L based on Uhlig & Bhat, 1979.
Models E, M, N and O based on Keddie & Cleghorn, 1980.
Models H and K based on IDRC, 1976 and Eastman, 1980.
Model G based on personal observations of one of the authors.

assuming the production of one type of meal, with bran and germ as occasional byproduct.

		Merchant milling				
G	H	K	L	M	N	O
Engelb. dehuller, hammer mill	PRL/RIIC dehuller, hammer mill	PRL dehuller, hammer mill, semi-auto packing	roller milling system, manual packing	degermer, roller milling system, manual packing	degermer, roller milling system, manual packing	degermer roller milling system, automatic packing
diesel	diesel	diesel	electric	electric	electric	electric
20-25	20-25	40-50	90	175	420	420
3[2]	3	8[3]	58[3]	53[3]	110[3]	71[3]
400	400	933	2083	2083	5000	5000
4	6	6	22.8	22.8	22.8	22.8
300	250	250	300	300	300	300
480	600	1400	14250	14250	34200	34200
.	.	.	.	.	.	.
.	.	.	90	.	.	.
60	80	80	.	78	78	78
.	.	.	.	.	.	.
5	5	5	2	2	2	2
96	160	140	221	210	243	376

gies against different technical criteria.

(1) The extraction rate at which different products are produced is of importance in regard of the markets aimed at and of the overall efficiency of the mill. As there are no generally applicable standards for such products the table shows estimated figures for the general categories degermed, bolted and whole meal. Roller milling systems give the highest yield of degermed or bolted meal from maize.

(2) The capability of a mill to manufacture a range of products according to demand can be an important criterion. This depends on the equipment used. Roller mills can, within limits, be adjusted to produce all 3 grades of meal in varying quantities according to demands. They are however designed for one raw material and if the feedstock is changed then the alterations of the rolls, sieves and conditioning equipment necessary to achieve a good recovery rate may be greater than is feasible. Disc, stone and hammer mills are used to produce whole meals, not only from maize but also from other cereals, legumes and dried root pieces. In combination with a simple dehuller they can be used for producing maize grits and all qualities of maize meal or for dehulling and grinding legumes and other feedstocks. Equipment, such as hammer mills and the PRL/RIIC and Engelberg dehullers, which is suitable for both continuous and batch operation may be used for service milling during the day in combination with merchant milling at times when there are no customers.

(3) The supply of raw material must be suitable for the scale of the milling operation. In the household sufficient maize must be obtained to feed the family from one season to the next with maize meal produced at the extraction rate achieved by traditional methods. A service mill must plan its capacity with regard to the number of potential customers within a reasonable distance, the quality of meal they wish to produce and the price they are willing to pay for the service offered. A merchant mill requires a steady supply throughout the year to operate profitable. The need for storage facilities, transport and supply contracts must be considered in relation to the competition for maize by other users.

(4) All size reduction operations require a continuous and preferable steady supply of energy. The availability and reliability of sources of electric, diesel, wind or water power must be considered along with the need for a back-up energy supply.

(5) Merchant mills must have an adequate supply of packing materials, usually of a defined size and quality.

(6) The location of a mill depends on its sources of raw material and energy and on its market. Merchant roller mills are located in large urban centres because of the local requirement for prepacked meal and the availability of transport and energy supplies. Hammer mills, which may operate in either merchant or service sectors process smaller quantities and are also suited to small towns and rural areas. They are better adapted to areas where the power supply is restricted. These regions may have poor road and rail connections or are not connected to the national grid. However even in areas where people have maize at their disposal the utilisation of a custom mill depends on its accessibility.

(7) The availability of skilled personnel for operation, maintenance and repair of equipment and for book-keeping and management can pose a problem.

Roller mills require a number of workers with specialised knowledge which can only be obtained from millers' schools, mostly abroad, or from experience in another mill. In several African mills the posts of manager, head miller and chief mechanic are held by expatriates. Wheat processing roller mills in South Asia often employ consultants for the first few years of operation (Uhlig & Bhat, 1979).

One person with a basic education can usually cope with the maintenance and management of a custom mill after a few weeks training. Equipment repair can be trusted to a mechanic not employed by the mill. Similarly the manager and miller/mechanic in a merchant hammer mill can be trained without great expenditure. A comparison of the total cost of training personnel for a roller mill and for a number of custom mills or merchant hammer mills with the same output would be of considerable interest.

The importance of maintaining household milling equipment is often underestimated. There is generally a lack of service information about newly introduced equipment.

(8) The choice of equipment supplier is governed not only by the type of machinery required but also by the availability of spare parts, delivery time and foreign currency for import transactions. It may be government policy to encourage the development of a local machinery manufacturing industry with the long-term aim of self-sufficiency. Such manufacturers can supply equipment, such as hammer mills, which can be used for many purposes more readily than specialised systems (Uhlig & Bhat, 1977; 1979).

Economic aspects

(1) The market(s) at which production is aimed is an important consideration in the choice between custom milling and merchant milling. For the consumer the choice between obtaining meal from a custom mill and purchasing similar meal from a merchant mill through a retail distribution outlet depends not only on the possible difference in price, but also on the time and effort required as well as on the product quality.

In rural areas where maize is regularly grown and is thus available for the majority of people, the interest in merchant mill products and buying power for them will be very low. In urban areas this is completely different. The buying power may be larger because of paid labour and it may be difficult to obtain maize kernels.

The prices of maize and maize meals are often regulated by the government if they are important staple foodstuffs. This is mainly of importance for the merchant milling sector and the urban consumers, as the government is only able to control official trade in maize and packed maize meal.

Substitution among staple foods in times of shortage or high price must also be considered. The closest substitute for degermed maize meal for a high income urban consumer may not be bolted or whole maize meal, but white rice, wheat bread, plantains or another staple fitting to his income and standards. For the whole maize meal consumer (poor rural or poor urban areas) the closest subsitute might be the whole meal of another cereal or root crop.

The choice of milling system and product is made on the basis of the expected level or profitability. This depends on prevailing demand, the distribution system and raw material and product prices. To obtain this information a market survey where possible is required. In any case a description should be made of the possible number of consumers interested in a specific product, the time, money and effort they are willing to spend obtaining it and their level and source of income. Further details of consumer behaviour and living conditions are helpful. The extent to which other products are used as substitutes for maize should be known.

The effectiveness of proposed distribution systems and sales promotion campaigns has to be evaluated. For a merchant mill this may be the choice between maintaining delivery vehicles and making use of an independent transport organisation. Custom mills should consider providing a transport service (ox-cart, small pick-up truck) to increase the number of households which can be served.

It is possible to combine custom and merchant activities in one hammer mill if the market for one of the systems alone does not guarantee profitable operation.

(2) In our opinion the most interesting of the few economic evaluations published is that of Keddie & Cleghorn (1980). In their study a comparison of a custom hammer mill producing only whole maize meal with three merchant roller mills is made. The roller mills produce degermed meal and bran at different scales with either a manual or an automatic packing line. The data for the hammer mill (column E) and the roller mills (M, N and O) are presented in Table 41.

Table 42 shows the results of a comparative cost and revenue analysis along with some economic co-efficients. Although we prefer to calculate annual costs and benefits, and discount the cash-flow over the total project period, the method of showing present values of different costs and revenues used by Keddie & Cleghorn also gives insight into the relative importance of several items. Further details are available in the original publication.

Although the capacity utilisation of the custom hammer mill is low and that of the merchant mill very high (Table 49), custom mills still operate very profitably, as shown by the Nett Present Values. Merchant roller mills show marginal profits only at the largest scale of operation with a low wages regime. Otherwise they show negative Nett Present Values (NPV's). The higher NPV's of the merchant roller mills calculated by Uhlig & Bhat (1978) under similar conditions confirm in the opinion of Keddie & Cleghorn the sensitivity (already demonstrated by Uhlig & Bhat) of roller mills to meal prices and their relationship to the costs of grain. In merchant roller mills, maize accounts for the lion's share of the total costs (in these cases for more than 75%), often followed by packing materials as the second largest item. The cost analysis of a merchant hammer mill producing dehulled sorghum meal shows a similar picture (Forrest & Yaciuk, 1980). The profitability of merchant mills thus depends mainly on the margin between meal prices (and prices of by-products) and maize prices, both of which are often controlled by the government. Merchant mills also need a large amount of working capital.

Custom mills get their revenues only from milling (or gristing) charges. As costs do not involve the purchase of maize and packing materials, these mills are not affected by maize and meal prices. Milling charges are generally a small fraction of the price of maize (about 5 to 10% in East Africa) and are hardly ever fixed by the government. Although they assumed gristing charges less than half of those quoted by Keddie & Cleghorn, Uhlig & Bhat concluded that hammer mills and water-powered stone mills were profitable when operating in the custom sector at the usual utilisation rates. A comparison with Stewart's (1978) results is more complicated, as her economic evaluation does not include the difference in commercial basis between a custom mill and a merchant mill by omitting the costs for packing storage and administration.

That merchant mills are subject to government regulations with respect to wages, working hours, maize and meal prices, while custom mills are hardly affected by external control, shows the dualism in the economy of a developing country. Both Stewart (1978) and Keddie & Cleghorn (1980) warn that one has to be careful with the interpretation of economic results, even on a national basis, because the technical data especially on custom mills (e.g. theoretical capacity, utilisation rate and milling charges) may vary considerably within one country. The figures assumed in their economic studies may only be rough estimates applicable to the case in question but of no general value. As custom mills operate in a different economic environment form merchant mills, Uhlig & Bhat (1978) do not compare them. 'This would require the use of a social cost-benefit analysis, valuing the time and effort of the consumer. Such a social cost-benefit analysis can only be made for a specific location'.

Socio-economic aspects

(1) The main concern in countries where maize is a staple food is probably the availability of sufficient food of acceptable quality and low cost. Milling is only one step in the food production chain and changes in any one stage can affect activities in one or all of the others. The product of lowest cost and highest nutritive value which gives the highest recovery rate (whole maize meal) does not always have an acceptable quality or storage life.

(2) On an equivalent output basis, custom mills and merchant hammer mills provide only a few more jobs than merchant roller mills. If the figures are corrected for the smaller number of working hours per day, custom hammer mills which produce only whole meal employ less workers than a merchant roller mill with an automatic packaging line. The saving in investment per labour place (Table 42) may however provide opportunities for creating jobs elsewhere in the economy. It is difficult to compare investment per labour place using figures from different projects executed at different times. A good comparison of the IDRC dehuller/hammer mill system with the data given in Table 42 can therefore not be made.

(3) Not all technologies are appropriate for an economic and social development which involves the majority of the population. Large-scale projects often require expatriate management, specialised technicians and sophisticated equipment. This demands a large part of the available foreign exchange or requires foreign investment funds and can result in dependency on industrialised countries. The introduction of small rural mills may create employment and thus reduce the drift of the population into towns. The establishment of such mills, be it as private or co-operative enterprises, also promotes the development of local entrepreneurial talent, management and technical skills. Re-investing profits from small milling enterprises or co-operatives may stimulate other activities in rural areas. The use of small dehullers and hammer mills may encourage the development of a national machine manufacturing industry.

Socio-cultural aspects

(1) When maize meal is a staple food, the quality of the product and the social acceptability of those processing operations that still need to be done in the home play a crucial role. In general, consumers are very critical of the palatability or organoleptic qualities of their staple. Whole maize kernels are only eaten, after boiling or roasting, prior to or just at maturity while they are still tender. Immature and just mature undried maize kernels cannot be stored unless preserved, usually by relatively expensive methods like canning or freezing. Fibre content, particle size and rancidity may play an important role in determining palatability of maize meals. The existing methods of food preparation, eating habits and organoleptic standards should be carefully studied before trying to introduce a new technology.

Table 42. Comparative costs and revenues for various types of maize mills (prices 1976). (from Keddie & Cleghorn, 1980)

Project type	Custom mill	Merchant mill	Merchant mill	Merchant mill
Equipment	Hammer mill	Degermer + roller milling system	Degermer + roller milling system	Degermer + roller milling system
Packing	-	manual	manual	manual
Initial investment in fixed assets (US$)	7080	368000	561000	720000
Total number of workers	2	53	110	71
Product	whole meal	degermed meal	degermed meal	degermed meal
Recovery rate (%)	99	78	78	78
30 year present values at 10% discount rate (US$. 10^3)				
Costs				
Maize	0	17500	41997	41997
Packing materials	0	2370	5686	5686
Energy	5.7	521	1098	1098
Labour				
at low wage	9.2	543	728	635
at high wage	32.7	1194	1976	1976
Fixed assets	8.5	470	716	948
Other costs	4.0	702	1683	1683
Total costs				
at low wage	27.4	22106	51908	52047
at high wage	50.9	22757	53156	52982
Revenues				
Gristing charge	76.5	0	0	0
Degermed meal	0	19921	47810	47810
Bran and germ	0	1772	4252	4252
Total revenues	76.5	21693	52062	52062
Net present values				
at low wage	46.1	-413	154	15
at high wage	25.6	-1064	-1094	-920

Economic coefficients				
Initial investment per labour place (US$)	3540	6940	5100	10140
Raw material processed per labour per year	360	269	310	482
Energy costs per tonne of maize (US$)	0.84	3.88	3.41	3.41
Labour costs per tonne of maize (US$)				
at low wage	1.37	5.18	2.89	2.53
at high wage	4.87	11.40	7.86	6.24
Production costs per tonne of maize (US$)				
at low wage	4.03[2]	161	161	161
at high wage	7.50[2]	168	164	164

1. Wage levels are at high wage regime for management, skilled and low-skilled labour resp. 5, 3.5 and 4.5 times higher than at low wage regime.
2. These production costs are low because raw material is not a cost at a custom mill. For merchant mills maize costs are 130.- US $/tonne.

In Africa it is traditional practice to remove at least part of the bran and germ before processing maize into meal that is later to be consumed as a dough, porridge or gruel (Schlage, 1968; Muller, 1970). It has been reported that when using hand operated mills such as disc mills the bran is discarded by sifting (O'Kelly, 1973, p. 119; CCT, 1980). Stewart (1978) found that this fraction may range between 2 and 25% of the weight of grain (Table 41). In mills, equipped both with a hammer mill and an Engelberg-type dehuller, most people paid for their maize to be dehulled before grinding. A student in food technology originating from Northeast Tanzania stated that in general whole meal was only used if it originated from freshly matured maize. The question may be asked: 'To what extent do people in rural areas eat whole maize meal?' For those eating whole meal, the benefits of a labour and time-saving technique may have outweighed the decrease in palatability. Research is necessary to check whether whole maize meal is sieved before further preparation as whole wheat meal is in India.

The preference for white, sifted meals in East Africa is associated with higher status. This may be enhanced in urban areas by the fact that merchant mills only advertise and try to create brand-loyalty for degermed meals. Stewart (1978) and Uhlig & Bhat (1979) report that in urban areas whole meals are considered as an impure, uncivilised, poor man's food. Witsenburg observed in Tanzania that this also holds in rural areas. Although little commercially produced degermed meal has been sold outside towns, degermed meal is traditionally manufactured.

A family has the choice between various levels of convenience: (a) travelling to a retail shop and buying meal, (b) obtaining maize and processing it at home, (c) obtaining maize and taking it to the custom mill to be degermed and ground, while sifting is done at home.

The price of the final product influences what kind and quality of product is chosen for consumption.

The fuel requirements for preparing products may differ. According to Keddie & Cleghorn (1980) degermed meal requires a shorter cooking time and therefore less fuel than whole meal.

The shelf life of maize meal also has an important effect on consumer choice.

The minimum quantity of the product which is available is an important aspect in particular for the urban poor. As custom milling is conducted in batches generally not smaller than 5 to 15 kg, a quantity of maize which would supply the family for several days, has to be bought at once. Prepacked meal (whether whole or sifted) may be purchased in smaller quantities to match the immediate purchasing power.

The consumer's choice meal is seldom determined by its nutritive value. Table 43 shows the effect of various milling processes on the chemical composition of meal losses of nutrients during milling are not the only ones occurring between harvesting and consumption. Reliance on one foodstuff as the major component of the diet leads to one-side nutrition. If the government wants to ensure good nutrition of the most vulnerable groups, fortification of maize meal with limiting nutrients should be considered as a last resort rather than a common solution. The costs of fortification procedures should be compared with those of a nutrition education programme, aimed at long-term improvements.

(2) The degree to which family labour is reduced by a certain technology, is also an important aspect. Often the advantages of a new technology are less than expected. The capacity of a hand operated disc mill is 16 to 20 kg/h (FAO, 1979). Compared with the 1.5 to 2 hours of labour that is necessary to pound the 1.5 to 3.5 kg of maize that a family needs for one day, this

Table 43. Effect of various maize milling techniques on the chemical composition of the produced meal (composition per 100 g of product)

	Energy (10^3 kJ)	Moisture (g)	Protein (g)	Fat (g)	Carbo hydrates (g) (incl. fibre)	Fibre (g)	Ash (g)	Calcium (mg)	Iron (mg)	Thiamine (mg)	Ribo-flavin (mg)	Niacin (mg)
Dried whole grain[1]	1.52	12	10.0	4.5	71	2.0	1.2	12	2.5	0.35	0.13	2.0
Dried whole grain[2]	1.45	13.5	8.5	3.8	70	2.7	1.2	.	.	.	.	.
Trad. degermed grits (pur)[2]	1.40	16.2	7.4	1.1	74	1.0	0.4	.	.	.	.	.
Trad. degermed meal (ungu)[2]	1.09	35.7	5.7	0.9	57	0.5	0.2	.	.	.	.	.
Whole maize meal[3]	1.49	12	9.2	3.9	73.7	1.6	1.2	10	2.4	0.38	0.11	2.0
Bolted maize meal[3]	1.52	12	9.0	3.4	74.5	1.0	1.1	6	1.8	0.30	0.08	1.9
Degermed maize meal[3]	1.52	12	7.9	1.2	78.4	0.6	0.5	6	1.1	0.14	0.05	1.0
Degermed maize grits[3]	1.52	12	8.7	0.8	78.1	0.4	0.4	4	1.0	0.13	0.04	1.2

1. Platt, 1962.
2. Schlage, 1968.
3. Watt & Merill, 1950, as quoted in FAO, 1953.

seems to be a considerable improvement. However, as the maize has to be passed through the mill 2 to 3 times with intermediate sifting, this mill also requires quite some effort.

The traditional type of milling and the availability of service (hammer) mills strongly influences the adoption of hand-operated mills. The introduction of the hand-operated disc mill in 1956 in West Cameroon for instance became a success as it was considered by both women and men an alleviation of the heavy job of saddle-stone grinding (O'Kelly, 1973). In scarcely populated areas of Northern Tanzania, however, the introduction of a similar mill in 1980 failed, partly because the mill showed only a slight improvement in productivity over hand pounding, and partly because any improvement of hand pounding was associated with the already known hammer milling, even although this technology was not available for the villagers because the custom mill was too far away (CCT, 1980).

(3) Socio-cultural customs related to certain activities may also play a role in the introduction of new equipment. The pedal operated hammer mill, developed by the Tropical Product Institute (Pinson, 1978), was not adopted by Tanzanian villagers, because of its low output (see Section 13.4.2, Household milling) and for socio-cultural reasons. The mill was originally intended for bicycle owners who are predominantly males, although milling is a woman's job. Many male villagers consider it to be a waste to use a bicycle for grinding even if it is specially provided for this purpose. As traditionally only men ride bicycles, women are not prepared to use a bicycle with their feet to drive a mill. 'Such is their reluctance to use the bicycle that we were told of instances when women got down on their knees and turned the pedal by hand' (CCT, 1980).

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14 Final remarks and bibliography

The need for a new approach to technological development arises from the difficulties encountered in bringing projects and programmes to a conclusion which is satisfactory for all parties concerned. A new flexible target group oriented approach to the selection of a food processing technology has been proposed as the most likely way of finding a solution which fulfills all the requirements of the people needing help. The approach is neither a new philosophy for tackling development problems nor an extension of any existing strategy. It is however an aid to choosing the best alternative from the selection of technologies proposed to solve a particular problem. Circumstances will dictate whether any project or programme falls within the scope of one development philosophy or whether a new approach which combines elements of several philosophies is necessary.

It is not possible to make a list of all conceivable factors which can affect the selection process in any particular case. Using sugar cane, cassava and maize processing as examples, the range of controlling factors from technological to socio-cultural has been illustrated. For other commodities and other processing problems the factors will be different, but the approach the same.

When presented with a problem, the reader should realise that it may have aspects not mentioned in its initial definition which are of critical importance to the success of any proposed solution. These aspects can only be evaluated after a close dialogue with members of the target group on their definition of the problems and their reaction to suggested solutions.

Decision making also requires information on the composition and structure of the raw material as well as some knowledge of its production, processing and storage. Background information on the production, composition and processing of commodities not discussed in the text can be obtained from the bibliography at the end of this chapter. As far as possible the references are grouped by commodity and presented in lists which begins with publications on the production of the foodstuff and continue with its composition, processing and storage. A more extensive bibliography arranged in a similar manner has been compiled and is available from the:

International Course in Food Science and Nutrition
c/o Lawickse Allee 11
6701 AN Wageningen
the Netherlands

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