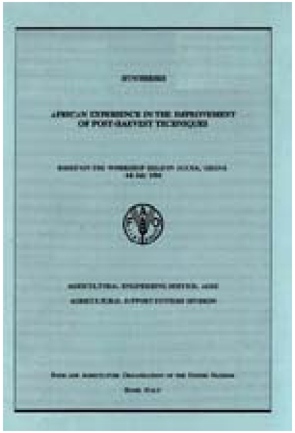

African experience in the improvement of post-harvest techniques

Based on the workshop help in ACCRA, Ghana 4 - 8 July 1994

Agricultural engineering service, AGSE
Agricultural support systems division

Food and agricultural organization of the United Nations
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Foreword

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The objective of this synthesis is to provide an updated analysis of the evolution of postharvest technologies used for the processing and conservation of grains and tubers by African farmers. These technologies permit to ensure food security to rural families, and avoid losses during harvesting, threshing or damage by pests or inadequate processing methods. Farmers will only increase their production if they are provided with adequate post-harvest techniques.

The majority of post-harvest techniques used in Africa are still based on traditional practices, however, there has been a large effort to improve existing practices. There have been various post-harvest projects executed by several organizations and a large number of projects operated by the Agricultural Engineering Service (AGSE) and the Prevention of Food Losses Programme (PFL) of FAO.

This synthesis has been based on a collection of data from FAO projects as well as on contributions of the participants in the Workshop on African Experience in the Improvement of Post-Harvest Technology, organized in Accra in July 1994 by the Ministry of Agriculture in collaboration with the Agricultural Engineering Service of FAO (AGSE). The Government of France and the Prevention of Food Losses Programme of FAO have provided a financial contribution to the Workshop.

Without pretending to be exhaustive, this synthesis will present, for each stage of the post-harvest process, both traditional and improved techniques of interest to African producers.

This publication has been written by Mr. Aliou Diop and revised by Mr. El Houssine Bartali amd Ms. Ccile Gurin (FAO Consultants). Its production has been supervised by Mr. Francis Troude and Ms. Annemieke Schoemaker. Our special thanks go to Mrs. Beatrice GraniPolidori of the Agricultural Engineering Service (AGSE) for the presentation of the synthesis in its final form.

A.G. Rijk
Chief
Agricultural Engineering Service
Agricultural Support Systems Division

Introduction

This report describes the evolution of post harvest technologies employed in the conservation of grains and tubers in Sub-Saharan Africa. The triple objectives of this study are: to review existing technology, to permit the wider dissemination of successful developments, and to reflect on the means to adapt certain technologies to the actual environment. This synthesis has been carried out following the "Workshop on African

Experience in the Improvement of Post-Harvest Technology" organized in Accra in July 1994 by the Government of Ghana, and from a review of published data resulting from FAO field projects.

These traditional technologies are described in detail in this report. In addition, developments in new technology will be revealed together with their impact and their dissemination among interested populations. Causes of the limited success enjoyed by certain innovations will be discussed as well as the insufficient consideration of the needs of the actors involved in the development, poorly evaluated economic and social criteria, and the lack of global vision of the post-harvest system.

Account will be taken of the evolution of a socio-economic environment in the postharvest system in order to better understand and anticipate future technological changes. Numerous factors impinge directly on post-harvest techniques, in particular the liberalization of commerce, the decrease in local production due to desertification and the relative reduction in the farm work force.

Numerous development projects and agricultural research bodies focus on post-harvest problems relating to food products. A great deal of effort is thus invested in the quest for appropriate solutions to these problems. This report is a synthesis of different technologies employed in the conservation of grains and tubers which does not pretend to be exhaustive. The structure of chapters follows the post-harvest process: harvest, threshing or shelling, drying, storage, control of predators, quality control, and processing. A sole chapter concerns the conservation of roots and tubers.

Chapter 1: Traditional post-harvest systems and their evolution

This chapter describes the various ecological, technological and economic changes which have profoundly modified the environment post-harvest system. It must be noted that experience of the improvement of traditional technology has enjoyed varied success, often neglecting the "human" side of development. This aspect, appearing as a thread running through the report, is dealt with in more detail at the end of this chapter.

1.1 Evolution of the environment

From time immemorial, rural agricultural producers have always sought to improve their techniques and methods of production, of handling and of conservation of the crops on which they depend for the survival of their families. Traditional post-harvest techniques for food crops are thus the result of a long process of experimentation and adaptation which have been largely empirical. After many centuries and generations they have perhaps approached a certain degree of perfection. This is explained by the constant necessity to find appropriate solutions based only on resources available in the local environment.

These techniques have been applied in an economy essentially oriented towards subsistence and self-sufficiency. The patriarchal family played therein a preponderant role with the functions and tasks defined in terms of gender, age and social rank. The exchange of goods and services was hardly monetarized and urbanization poorly developed. However, the phenomena of desertification and massive emigration as a result of drought did not have the amplitude which they demonstrate today. Thus, since one generation at least, consecutive changes are observable in response to new constraints in the operation of traditional postharvest systems.

1.1.1 Modification of ecological conditions

Deforestation

In many African countries, the natural materials used for construction of grain stores have become rare or have even disappeared through the effects of deforestation (increase in land clearing and urban expansion), of desertification (climate) and of the use of improved, short-strawed varieties of grain.

This relatively new situation has brought about different construction methods for storage structures with the use of alternative materials (Chapter 5) and the quality of storage has sometimes diminished (figure 1.1). Also, the problems of desertification and prolonged drought have resulted in reduction of long term stocks which assured food security for the rural population. This almost total disappearance of traditional reserve stocks has stimulated village initiatives to develop communal storage structures, notably cereal banks (end of Chapter 5).

New Predators

In certain regions new predators have appeared. Notably, a storage pest, Prostephanus truncatus (The Larger Grain Borer) discovered in Tanzania. This insect is now widely spread in East and West Africa. It remains difficult to control by traditional methods and causes heavy losses. This point is further discussed in Chapter 6.

1.1.2 Technological change

New equipment

The introduction of new post-harvest equipment generally permits an increase in working capacity and productivity among farmers. Technological innovations may always be found to be ill-adapted if they are set in motion without taking into account the whole postharvest system. This is composed of a suite of interdependent operations. Any modification to one operation produces more or less serious effects on other operations and may destroy the equilibrium of the system. For example, the introduction of mechanical threshing leads farmers to change towards storage of grain rather than unthreshed ears (Chapter 5).

Improved varieties

The introduction of new, high yielding varieties tends to increase production and begins to solve the problem of food deficits. Nevertheless, new problems arise: the farmer must address problems in handling and storage of larger volumes of grain and, in addition, the new, more productive varieties are more susceptible to insect attack. They often exhibit greater tenderness or a sheath which does not ensure complete protection for the ear.

Chemical pesticides

Traditionally, farmers use various types of natural insecticides of either vegetable or mineral origin to preserve their grain from insect attack. These methods are described more precisely in Chapter 6. For some decades the employment of visibly effective chemical products has been very successful among farmers. Actually, certain products, on free sale in local markets can, if badly used, have serious consequences both on the effectiveness of the treatment and the health of consumers. This situation, discussed further in Chapter 6 of this report, is due to the absence or non-application of appropriate legislation on the subject.

1.1.3 Socio-economic changes

In the majority of African countries the production of food crops has changed during the past thirty years from a subsistence economy to a market economy. On one hand the monetarization of the economy obliges the farmer to sell part of the crop to satisfy new needs. On the other hand rural areas, affected by the phenomenon of exodus, must produce more to respond to the growing demand of urban areas. The increase in production per farmer implies needs at different levels of the post-harvest system. For example, at the level of storage, the initiation of grain storage in bulk stores is a consequence of several socioeconomic changes such as: overlapping several post-harvest operations and the lack of time for construction of new granaries, increase in demand for storage capacity, fear of theft and fire, and the evaluation of social status as a function of the storage utilised. This point will be discussed in depth in Chapters 4 and 5.

1.2 Improvement of post-harvest techniques

1.2.1 History of improvements to post-harvest operations

Before discussing the new techniques now established, we will rapidly examine the experience gained in the 1970s and 1980s. The first steps to improvement of post-harvest techniques during the 1970s were focused on the storage of millet and sorghum in the Sahel zone following periods of drought and famine. In these ancient post-harvest systems based on self sufficiency the losses during storage were somewhat neglected by the farmers as long as people did not perceive losses to affect household food security severely. The quality of storage assured food security, and there were ancient traditions in the production, handling and conservation of millet and sorghum.

Since the end of the 1970s numerous research and development programmes prioritized action on maize and rice which constituted the basic food for people in many countries.

Maize:

The main focus has been on drying and storage. Since the end of the 1980s priority was given to the improvement of traditional systems (Chapters 4 and 5).

Operations of shelling and milling were little studied. Equipment for improvement of these operations was introduced (Chapters 3 and 7).

Rice:

The policies of liberalization of the economies of Senegal, Mali, Cameroun and Burkina Faso in the 1980s established a process of disengagement of parastatal bodies from the post-harvest processes in rice. The need for intermediate technologies adapted to the threshing and processing of rice at village level greatly increased in the last few years. Interesting trials (adaptive research and distribution of appropriate equipment) were conducted on the operations of husking, threshing and drying (Chapters 3, 4 and 7).

1.2.2 The human dimension in the development of post-harvest systems

The majority of development workers, executing agencies and extension specialists have long under-estimated the importance of the role of women in the economy of their countries and in post-harvest activities linked to the treatment, processing, conservation and marketing of food products. Because of their confinement to the home, women have little less mobility and little time; moreover they have limited access to education and financial or material resources. The lack of accessible and affordable technology, taking account of the needs and constraints of women is a constraint for development. This often leads to a loss of control for the women over current technology and transfer of employment opportunities and income to the men.

An in depth analysis of the distribution of tasks between women and men in the context of the agricultural enterprise as well as the identification of the needs and constraints of women (for the activities of storage, processing and marketing) is necessary if innovations in postharvest technology are to reach their potential beneficiaries.

Chapter 2: Conservation of roots and tubers

2.1 Introduction

Roots and tubers occupy an important place in the nutrition of the people and in the economy of some African countries, in particular those situated along the Gulf of Guinea. For some ten years, development assistance programmes have intervened at the post-harvest stage for roots and tubers under the same heading as for the long-privileged cereals. Yams and cassava are the two crops principally cultivated. This explains the volume of activity in research and development which have been devoted to them compared with other roots and tubers.

Roots and tubers constitute a good source of energy (see table 8.1), minerals and vitamins. The yields in calories per unit area are comparable to cereals. The quantity and quality of proteins are variable and relatively low in terms of fresh material. On a dry matter basis, their protein content is as good as cereals. Traditionally, dishes based on roots and tubers are accompanied by high protein foods (meat, legumes and pulses).

Roots and tubers have a high moisture content (up to 90%). This cumbersome produce, fragile and variable in shape, is damaged at all stages in the post-harvest handling chain, causing losses (for yams, 25% to 30% of losses registered in three months).

These constraints linked to the characteristics of roots and tubers make it difficult to process and market fresh products in urban centres. Despite several attempts at processing, often artisanal, the technology for adding value to these products remains under-exploited.

Table 2.1 - Level of nutritive elements in food products

	Maize	**Sorghum**	**Paddy**	**Cassava**	**Yam**	**Sweet Potato**
Average yield (kg/ha)	336	746	1,756	6,182	9,973	5,893

% Unusable	60	10	35	26	16	21
CALORIES						
Per 100g useable	359	347	364	149	119	121
Per ha/season (1000)	4,137	2,330	4,155	6,816	9,969	5,633
Rank	5	6	4	2	1	3
PROTEINS (g)						
Per 100g useable	9.3	11.1	7.0	1.2	1.9	1.6
Per ha/season (kg)	112	75	80	55	159	75
Rank	2	4	3	6	1	4

(Source: FAO, 1985 - Report of the Workshop on Production and Marketing Constraints on Roots, Tubers and Plantain in Africa, Vol. 1)

2.2 Cassava

Cassava is a security crop for many farmers: it is well adapted to climatic conditions,

even extreme drought and to different types of soil. It needs little inputs or labour. The roots can be left in the ground in order to delay harvest. The experience brought to bear on cassava concerns storage and processing, two operations which add value to the product.

2.2.1 Storage of cassava

Cassava roots deteriorate rapidly two or three days after harvest (physiological factors) or five to seven days after harvest (activity of micro-organisms) (Cooke et al. 1988). Several techniques for conservation of cassava roots in a fresh state have been tested: covering the root with a film of paraffin wax, or mud, or moist ash; storage underground; blanching with boiling water; immersion in cold water. These techniques have enabled conservation to be prolonged for two to ten days but they are laborious and sometimes costly for major quantities.

- **Storage of the roots under plastic film**

In Ghana, Gallat (1994) describes a technique developed by CIAT (International

Centre for Tropical Agriculture) and the NRI (Natural Resources Institute). It consists of a "mobile" system of storage based on packing the roots in plastic film combined with chemical treatment to control microbial rot. The roots can be conserved for an extra two weeks in good condition to suit the requirements of merchants and consumers.

- **Storage of the roots in moist sawdust**

Agboola (1994) describes a technique for conservation of cassava roots in sawdust which is kept moist in baskets or wooden boxes. The cassava is conserved in good condition in a cool place for almost two weeks as long as the roots are of good quality and without bruises to begin with. This technique, introduced in Nigeria among peasant farmers and small traders, has not achieved an appreciable level of adoption.

In Uganda, a similar technique has been tested with storage trials in moist sawdust or moist wood shavings (Nahdy, 1994).

Technical Description

Trials were held with cassava harvested less than 8 hours earlier (Tereka variety), on

healthy batches and on damaged batches (2-3 cm removed from the tip of the root). Polythene sacks with perforated bottoms were placed in compartmented wooden boxes (170x65x80cm). Cassava roots were stored in three layers, alternating with sawdust or wood shavings. Storage of one batch in soil served as a control.

Results

- **Compared with the control technique, the improved storage method reduced deterioration due to microbial action, discolouration and mould. The freshness of the product was improved in comparison with traditional techniques.**
- **In the improved storage, the same results were noted in the case of both healthy and damaged roots. However, discoloration and mould were less noticeable on the healthy roots.**
- **The experiment has shown that it is possible to conserve fresh cassava for three weeks with this improved storage technique. After that, the level of moulding becomes unacceptable (50% after 40 days; 80% after 63 days). This simple, low cost technique using natural materials, could reduce the problems of storage and marketing for cassava in urban centres.**

2.2.2 Processing cassava

Cassava is transformed into two principal products, flour and gari, in order to detoxify and better preserve the roots. Processing, organized by women in rural areas, causes the loss of some of the mineral and vitamin value.

Cassava Flour

Cassava flour, very common in the marketplace, is relatively easy to produce, store and market. It is used to make foufou, a basic African foodstuff. To produce the flour, the cassava roots are soaked in water for 3-4 days, then peeled, cut in chips and dried in the sun. Finally, the chips are ground into flour. The quality of the drying operation is primordial if dangerous microbiological infections are to be avoided. This operation, which is carried out sometimes in the wet season (in high rainfall areas) is a serious constraint to production. The introduction of equipment to cut the cassava into thin chips would lighten the work of the women and facilitate drying.

Gari

Gari is a product based on cassava found frequently in African markets. In Nigeria, for example, it represents 70% of the cassava-based products (Sadik, 1987). In North West Cameroon, the women make gari manually: 3 bowls of 14kg per week in the wet season and 6 to 8 bowls in the dry season. The production of gari requires a whole series of operations: peeling, washing, grating, pressing, fermenting, sieving, cooking (or gasification) packing and storing. Some operations are problematic for the women occupied in this artisanal production (Flach, 1990).

- **The productivity of manual peeling which varies according to the size of the roots and the variety is about 20-25kg/h. The peel represents 25% (Flach, 1990). Several techniques for mechanized peeling or the use of chemical products have been developed but experience shows that they are inappropriate, costly and of no advantage compared with manual peeling.**
- **The productivity of manual grating is only about 20kg/h and the operation is very laborious. In comparison, motorized graters have a capacity of 2T/h (Sadik, 1987) and are used on a rental basis with success by private entrepreneurs and womens' groups.**
- **Traditional pressing consists of placing the grated cassava in a jute or woven**

polypropylene sack and pressing it under a rock or interlaced wooden logs. During this operation (3-4 days) fermentation takes place and the hydro-cyanic acid is partially eliminated. Hand-operated screw presses have been distributed with success in the villages.

- **In industrial units, cooking or garification is done in rotary ovens heated to 260 - 290C for 10 minutes, followed by drying for 8 minutes at 150C down to a moisture level between 9% and 12% (Sadik, 1987).**

The artisanal method consists of cooking each batch (2 to 3kg), stirring continuously, for 30 minutes in pots heated over wood fires. The final product represents 20% to 25% of the fresh cassava.

The principal improvement brought to this operation concerns the reduction of firewood consumption (Flach, 1990). In Cameroon, improved hearths of baked mud bricks, managed by groups of women on a rental basis have achieved a reduction of 50% in firewood consumption as well as reducing cooking time. However, the introduction of mechanized ovens has been a failure. For semi-industrial gari production, an appropriate cooking apparatus capable of drying the product down to 12% moisture content has still to be developed. This would permit packaging the gari in plastic bags and conserving and marketing it over several months.

2.3 Yams

The types of yam most cultivated in Africa are Dioscorea rotundata, or white yam; Dioscorea cayenensis, or yellow yam and Dioscorea alata. Yams reach maturity after 6 to 9 months and have a dormant period of 3 to 6 months, depending on variety.

2.3.1 Storage of yams

Traditionally, the yam store is an enclosure, partially shaded and constructed of vertical supports (wooden posts or live trees) about a metre apart and linked with bamboo slats. A straw roof and walls of woven plant material complete the structure. The yam tubers are hung (a laborious task) up to a height of two to three metres (Ezeike, 1994). This structure is popular for its simplicity and modest cost. However, the conditions of temperature and humidity are practically the same as the ambient air outside and thus not really favourable for storage.

2.3.2 Improved storage for yams in Nigeria

The Department of Rural Engineering at the University of Nigeria at Nsukka has designed a ventilated cellar for yam storage (Figure 2.1). The cellar measures 2.9m long by 1.3m wide and 1.5m deep. The roof, in the shape of a cupola, protects the cellar against penetration of rain water. Grilled openings (B in the figure) and a chimney (C) in the centre, improve the ventilation level. The chimney, painted black, accentuates air movement.

Figure 2.1- Ventilated cellar with central chimney; (a) Longitudinal Section; (b) Profile

A: Door;
B: Grille;
D: Stair;
E: Stairway Roof

This new storage structure, conceived for the conservation about 200 tubers, has been evaluated over 6 years and compared with traditional stores.

- **The temperature inside the cellar varied between 21.2C and 24.1C. Ambient air temperature and the temperature inside the traditional store were much higher,** varying between 30C and 40C.

- The weekly average of relative humidity in the cellar varied between 83.9% and 93%.
- These high levels of humidity combined with relatively low temperatures are close to the ideal conditions (25C and 96%) for damaged areas on the tubers to cure. Moreover, favourable conditions have permitted a reduction in weight loss due to respiratory activity in the tubers (Table 2.2).

Table 2.2 - Weight loss in yams under various conditions

Phase	**Weight Loss to Respiration (% per day)**	**Total Weight Loss (% per day)**	
		Cellar	**Store**
Harvest	0.076	0 25	0.25
Dormant	0.021	0.17	0.27
Germination	0.068	0.23	0.35

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2.3.3 Improved yam storage in Benin

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Two storage structures of about three tonnes capacity, made from local materials, have been evaluated under the FAO project "Decentralized Storage Systems".

Technical Description

- **The raised hut, a structure mounted on poles fitted with anti-rat shields (Figure 2.2).**
- **The cellar-hut, a trench 4m x 2m x 1.8m deep (figure 2.3). The mud walls are 60cm outside the edges of the trench, thus providing a space for movement. Wooden planks forming a duckboard placed in the bottom of the excavation and covered with straw insure good insulation of the tubers from the soil. Alleys arranged between the walls of the trench and the stacks of yams (30cm) and between the**

stacks themselves (50cm) facilitate air circulation and inspection.

- **The yams stored in both these structures were treated with Koufla(1) at a rate of 2.5kg per tonne of tubers.**

Figure 2.2 - The raised hut (Source: Fiagan, 1994)

Figure 2.3 - The cellar hut (Source: Fiagan, 1994)

Results

The improved method was compared with traditional storage (stacks in a hut) in two ecological zones in Benin, using early varieties (Kpounan/Labako) and late varieties (Gnidou). Quantitative losses were measured together with the quality of the tubers conserved and the value benefits obtained after 120 days of storage (Tables 2.3 and 2.4 below).

Table 2.3 - Percentage loss measured in Central Benin

Variety	Improved Store	Traditional Store

Early	24.2 %	57.3 %
Late	22.4 %	38.4 %

Table 2.4 - Percentage loss measured in North Benin

Variety	**Raised Hut**	**Cellar Hut**	**Traditional**
Early or Late	26.8 %	20.6 %	59.1 %

The good results shown above confirm the value of improved storage structures. With respect to quality, the higher moisture content of the yams stored in the cellar hut improved the preparation of pounded yam and thus the appreciation of the consumers.

With respect to the economic results, the study showed that the producer obtained for the early varieties a benefit of 220% in value with the improved storage (against 44 % with traditional storage). However, with the late variety the benefit was the same whatever the type of storage. There is a risk that the cost of the improved storage together with the phytosanitary treatment, especially after the devaluation of the CFA Franc in January 1994, could prove to be a constraint to the development of this type of storage.

2.4 The potato

The production of potatoes in Sub-Saharan Africa is often limited to high altitudes, notably in Kenya, Burundi, Cameroon and Nigeria. Introduced to these regions relatively recently, potato cultivation is accompanied by only rudimentary storage structures. The potatoes are simply heaped on the ground in a store room. They are put in jute sacks for marketing.

In Cameroon, in the North Western Province the potato represents a cash crop for the women who produce almost 75% of national output, estimated at 35,000 tonnes. The price fluctuates with the season. At its lowest after the first harvest (July-August), it attains double or triple its initial value in late November - early December (12 to 15 weeks after harvest). The majority of producers do not benefit from this increase because they do not store their potatoes beyond two months. The quantitative and qualitative losses are due mainly to rodents, to the short dormant period of the varieties grown and to lack of ventilation. Losses reach 4.4% per month during storage from January to June (second crop potatoes) and 5.5% per month during storage from July to December (Toes, 1982).

The FAO/UNDP project in Cameroon entitled "Development of Post-Harvest Systems", has designed and promoted a small mud structure for storing about a tonne of potatoes (Figure 2.4).

Figure 2.4 - Mud-walled structure for potato storage (Source: Hunt, 1982)

Chapter 3: Techniques for threshing, shelling and parboiling grain

Maize shelling and the threshing of rice, millet and sorghum are post-harvest operations which consist of separating the grain from the ear. For all these cereals, the traditional manual method is still widely predominant for this operation (Figure 3.1).

3.1 The rice harvest

Experience in rice harvesting has been gained in two fields:

- **Improvement of manual harvesting of rain-fed rice with the introduction of the Asian sickle in Gambia and Sierra Leone. The experiences mentioned below have been described by Manalili in "Introduction of the Asian Sickle".**
- **Mechanization of the harvest though the introduction of combine harvesters (Niger and Senegal River valleys) or motor-driven reapers (Madagascar project). A description of the acquired experiences through rice harvesting mechanization can be found in FAO Bulletin N 109.**

3.1.1 Observations on the traditional method

Rainfed rice or shallow-water rice is harvested manually by means of small knives, ear by ear, by women who gather them in sheaves (about 5kg of paddy) before transporting them to the homestead for storage. The harvest takes place at the beginning of the dry season. The method is slow and very laborious. Nevertheless, this

method of selective harvesting appears adapted to unselected varieties of rain-fed rice where panicle maturity is spread over a period of time.

Irrigated rice is harvested in Gambia with a fairly heavy European type of sickle (figure 3.2). This operation is generally reserved for men and should be effected rapidly because irrigated rice reaches maturity just before the rainy season. It is thus necessary to harvest and dry it as rapidly as possible.

3.1.2 Introduction of the asian sickle

The post-harvest project fielded by FAO in Gambia (1992) introduced the Asian type of sickle and was directed to training artisanal iron-workers in order to promote the local manufacture of such sickles (figure 3.2).

The advantages of the Asian sickle are:

- **Technical improvement: the sickle permits several stems to be cut at a time, close to the soil. The direction of cut and the shape of the teeth create a self-**

sharpening action for the sickle.

- Productivity gain: 122 hours/ha/person with a sickle compared with 721 hours/ha/person with traditional methods, or six times more labour required by the traditional method. This is a benefit in improved varieties (yield above 1.5T/ha, density above 200 plants/m^2).
- Reduction of losses by shattering through completion of harvesting in the ideal period.

The disadvantages are:

- More difficult threshing and higher losses because of the greater length of straw. However, threshing in the field permits a reduction of losses during transport.
- Greater physical effort in a bent position while harvesting.
- Necessity to use varieties which ripen at the same time but which are not always available.

In conclusion, the introduction of the new type of sickle, where local culture permits it, improves productivity and indirectly reduces post-harvest losses.

Figure 3.2 - The three types of sickle used in Gambia

3.2 Rice threshing

In the case of rice (also of sorghum)[2] the traditional technique consists of beating sheaves of rice with a wooden flail on a roughly swept threshing yard. This leads to a mixture of rice with debris of varied origin, notably soil and small pebbles; even metallic debris. Winnowing does not remove such debris completely. This is the principal cause of wear of the mill huskers which are seldom provided with pre-cleaners. Moreover, late harvesting due to shortage of labour leads to direct losses from shattering and indirect losses through cracking of the grain.

Observing that poor threshing conditions are counter-productive from the point of view of milling and final quality of the rice, research and development bodies have worked on the design and dissemination of improved threshing technologies.

3.2.1 The threshing table

With the objective of facilitating the threshing of long strewed rice at the site of harvesting, an FAO project has introduced a modified version of the threshing table used in Asia, adapted to local conditions (Manalili, 1994). Threshing is effected by beating sheaves of rice against an interwoven grille of bars forming an inclined trellis (Figure 3. 3). This model was modified during the course of the project by lowering the table with respect to the ground and by using branches of neem and mangrove, more resistant to termites, for the bars of the grille. A more solid metallic model has also been constructed for irrigated rice.

The threshing table has an average capacity of 20.8kg/h/person or 41.6kg/h with two operators. Where yields are higher (3T/ha) capacity can be doubled to achieve 80.6kg/h with two people. Moreover, loss of unthreshed grain are less than 1%

It is estimated that the use of a threshing table can save US$3.71 per hectare on the basis of an hourly wage of US$0.17 found in that locality. Compared with the cost of acquiring the table (US$4 for the wooden model or US$17 for the metallic version) the saving appears profitable.

Figure 3.2 - The threshing table (Source: Manalili, 1994)

3.2.2 Motorized threshers

Development programmes in the post-harvest sector have sought to mechanize the rice threshing operation with two objectives: to increase capacity for post-harvest treatment in order to alleviate time constraints under double cropping systems and to promote local fabrication of equipment to reduce investment costs.

Table 3.1 below lists the threshing equipment introduced or evaluated under various projects in the FAO Prevention of Post-Harvest Loss Programme (Visser, 1993). Among these models, the Votex thresher is the one which has been most often tested and which is the objective of local artisanal manufacture in Senegal and Mali.

Table 3.1- Threshing equipment introduced or evaluated under various PFL projects

Drive	**Name**	**Capacity in trials kg/in**	**Capacity by maker kg/in**	**Operators required**	**Country and date**	**Success**
Manual	Threshing table	20	-	1	Gambia (89-92)	yes

Pedal	-	48	-	2	Burkina (81-83)	?
Motor Motor Pedal	Votex Colombani -			3 1 2	Guinea (85 -91)	no no yes
Pedal " " " "	Askhat (India) Tikonko (S. Leone) Cecoco (Japan) Cecoco (China) Siscoma(Senegal) Agrima (Taiwan)	140 194 150 225		2 3 2 3 3 3	Liberia (79-81)	?
Motor "	Votex, Ricefan IRRI Axial Flow	180 165	200-1000 300-600	3 3	Liberia (79-81)	no: not adapted to long straw

Motor " "	lRRI, TH6 Votex, Ricefan IRRI, TH8	491 914 446	500 300-1000 500-1000	3	Madagascar (85-87)	no yes no
Motor "	Alvan Blanch * Midget MKII * Super MidgetII	70 45		2 2	Nigeria (1976)	?
Motor	Votex, Ricefan	450	300-1000	3	Senegal (90-91)	No: non-technical reasons
Motor " Pedal	Votex, Ricefan Miniagad (IRRI type) Cecoco	134.6 234.2	300-1000 450-675	4 4	Sierra Leone (83-85)	No Yes: profitable No

N.B. Yields indicated correspond to rice threshing; in certain cases threshers have been experimented with other products (Source: Visser, 1993)

3.2.3 The votex thresher

In this section the experience of the "Office du Niger" in Mali (rice growing region of 50,000 ha) is described. For more detailed information, see chapter 4 of FAO Bulletin N 109.

History

In the mid-1980s rice was threshed by tractors-driven threshers. Problems of drainage of the paddy fields and management of equipment led to delays of up to six months. Charges imposed on the peasant farmers amounted to as much as 12% of the value of the product threshed. In 198384, portable threshers, developed and tested in Mali, were evaluated, and a programme of extension, of agricultural credit and of operator

and mechanic training was initiated. By 1988, 500 Votex threshers had virtually replaced the old classic threshers managed by the Office du Niger (Tour and Wanders, 1994).

Technical Description

The Votex thresher is a simple machine; it only has one moving component, the toothed (or barred) drum of 400mm diameter (Figure 3.4). The drum and concave are mounted in a chassis to which are attached the transport rings. A hatch permits cleaning and adjustment. The drum is fitted with vanes and thus functions at the same time as a fan (initial cleaning), and 85 % of the threshed product is collected from below the thresher. A sheet placed behind the thresher collects the remaining 15 % of threshed grain. The rotational speed of the drum and the clearance between drum and concave are set to provide stronger threshing depending on the crop. The threshing capacity varies from 400 to more than 800kg/hour. This capacity permits in a two months threshing season about 60 - 100 hours work per thresher. Threshing requires a crew of 6 persons. Supplementary winnowing is generally carried out by women.

Advantages

Portable:
Small dimension and light weight (175kg)

Multi-functional:
Thorough threshing (minimum losses), facilitated product flow, initial cleaning.

Simple:
One moving part; two adjustments.

Robust:
Threshing teeth and fan blades in steel to resist abrasion from paddy.

Durable:
Threshing teeth need partial replacement once or twice per season (15,000FCFA). Concave needs replacement completely (100,000FCFA) or partially (25,000FCFA) after 3 or 4 seasons (1,000T of paddy). Drum and drum teeth need replacement completely after six seasons (1,500 T of paddy).

Contrary to the rejection suffered by the more imposing, classic threshers, this new VOTEX thresher which links ease of use to flexibility, has been rapidly accepted by the farmers because of its manifest advantages.

Figure 3.4 - The Votex Thresher (Source: Tour and Andraianarivelo, 1994, IRRI)

3.3 Parboiling rice

The fact that rice production in African countries is uncompetitive compared with Asian rice is explained largely by the cost of processing which is too high3. Milling efficiency does not exceed 60% and the proportion of broken grains (35-40%) is very high. As practiced in South East Asia, parboiling has spread very little in Africa, with the exception of Sierra Leone and Liberia. Up to 1990 in Cameroun all available parboiled rice was imported from Thailand.

3.3.1 Phases and advantages of parboiling

The phases are:

- **Soaking in warm water (50-60C) increases grain humidity (at least 30% moisture content) facilitating conversion of starch to gelatine.**
- **Steaming achieves a "gelatinization" temperature of 70C. In the gelatinous starch all cracks disappear.**
- **Drying the parboiled paddy, after cooling for a short period in the shade, is effected by spreading the paddy in the sun. Once moisture content is lowered to 16% or 18% the product is covered for 2 to 4 hours (resting or tempering). Then drying is resumed until moisture content is lowered to 14%.**

Parboiling is a steam treatment of paddy which alleviates the effects of poor drying (cracking) and improves yield quantitatively and qualitatively since the proportion of broken grains is reduced. (Diop and Wanzie, 1990). The cooking quality of parboiled rice is better because the grains stay firm and do not stick together. The rice is also more nutritious because the proteins and vitamins are diffused through the centre of the grain after parboiling. Lastly, parboiled rice stores better thanks to its greater hardness. Only its stronger flavour and yellowish colour could be disadvantages.

3.3.2 Experience of rice farmers in the north west of Cameroon

A parboiling technique was introduced based on a very simple method (Figures 3.5 and 3.6). A 200-litre metal drum is cut into two half drums. The upper half drum, the bottom of which is pierced with small holes, and which contains the paddy, is placed on top of the second half drum containing boiling water. A hearth of clay bricks minimises wood consumption (15kg of wood for 50kg of paddy).

Following this trial on a small scale, 25 % of rice marketed locally was parboiled; 55% was parboiled by the producers themselves, 45% was parboiled by small processing enterprises and one regional state enterprise (Diop and Wanzie, 1990).

Figure 3.5 - Equipment for parboiling based on metal half-drums

Figure 3.6 - Parboiling method with drums and perforated tubes

Above: Soaking in warm water
Below: Steaming the two batches

3.4 Improvement of methods of maize shelling

The traditional shelling technique found most often in Africa consists of using a stick to beat a sack full of dry maize cobs. This practice causes a relatively high level of cracking and consequently makes the grain vulnerable to insect attack. In several countries, where quantities are small, the women employ another method in which two cobs are rubbed together, causing the grains to fall. This method avoids cracking the grain but needs very dry cobs.

The introduction of a wooden sheller permitting manual shelling, cob by cob, has been tried in several African countries. This implement, of limited capacity better adapted to the shelling of small quantities for seed, has not been adopted by the people.

Mechanical, manually operated shellers have been introduced in the context of the fight against the Larger Grain Borer (Grand Capucin) to permit the grain to be stored and treated with insecticides. The operating principle of these machines consists of passing the cobs between two rotating toothed plates. Three or four operators are required and the output varies between 205 and 450kg/h.

Following the increase in quantity harvested and the need to use fan-assisted hot air dryers, the development of rental services for motorized shellers may be foreseen. In

the design of development projects of this type it will be necessary to take into account the respective roles of men and women in the shelling operation.

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Chapter 4: Grain drying

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This chapter discusses, in particular, the drying of rice and maize. After describing the traditional methods of drying, the various improvements possible will be examined. Grain drying has been described in FAO Bulletins N 40, 70, 109.

Most grain is physiologically ripe when its moisture content is around 30%. In this state it should be harvested rapidly to avoid attack in the field from predators and, in the case of rice, to diminish grain loss from shattering and cracking. The harvested grain is then dried sufficiently to minimise attack by insects and micro-organisms.

The key factor during drying is the humidity of the ambient air especially when drying is done without supplementary heat. Where there is only one rainy season, drying by natural air convection presents no major problems. For equatorial zones (two rainy seasons per year) drying conditions are not optimal.

4.1 Rice drying

Traditionally, drying rice in the sun poses no particular problems. In effect, in tropical regions the average level of insolation is greater than 0.5kw/m2 (that is, for 12 hours of sunshine a quantity of heat of 21.6MJ/m2) and this amount of heat is sufficient to evaporate 9kg of water.

- **In the case of rice harvested in the dry season, the problem is to control drying to prevent excessive heating and hydric stress4 in the grain. No studies exist of drying in sheaves or stacks, nor of drying in the field before harvest as is practiced by peasant farmers in Africa.**
- **For rain-fed rice harvested in periods of high relative humidity, some development projects have studied and extended models of drying floors based**

on various kinds of materials. Grain is arranged carefully on the restricted surfaces of purpose-built drying floors and the progress of the operation is carefully controlled. Results show that paddy can be dried (from 24-26% moisture content to 14%) in beds 50-100mm thick at a rate of 3.3kg/m2/h if the grain is regularly turned or 1.9kg/m2/h if the grain is not turned.

Under conditions of maximum insolation the grain can attain a temperature of 60C and the rate of drying is sufficiently high to provoke cracking and losses in milling. The drying rate should be reduced by covering the grain between mid-day and 3pm (in the experience of IRRI) when the weather is particularly sunny thereby reducing cracking by 25 % .

4.2 Maize drying

Maize drying takes place in the middle of the rainy season. Therefore, while the relative humidity remains around 80% for several weeks after the harvest, it is practically impossible, without additional heat, to reduce the moisture content of the maize to 13-15% at which it can be stored. Exceptionally, in the south of Nigeria, despite the humidity, maize cobs can be stored at about 20% moisture content in naturally ventilated structures in which it continues to dry for 1 to 3 months.

The humidity constraint is accentuated by increases in quantity harvested which are often beyond the drying capacity of the producers. A drying phase of varying length occurs in the field, on the stalk, although this practice leads to losses from predators. Also, after harvest, removal from field to homestead is delayed through waiting for transport. The result is considerable loss from fungal attack on the too moist grain (Table 4.1).

Table 4.1- Levels of loss during pre-drying of maize in the field

Source: FAO, AGS Bulletin N 40

	End of August		**End of September**		**End of October**	
	Forest Zone	**Humid Savannah**	**Forest Zone**	**Humid Savannah**	**Forest Zone**	**Humid Savannah**
Insect damage (%)	2.8	1 1.4	7 8	1 9	10.8	2 1
Weight loss due to insects (%)	0.9	0.7	2.4	0.6	3.2	0.8
Fallen plants	-	-	6.8	18.2	-	-

Loss due to Birds (%)	26	26	20	20	16	15

4.2.1 Drying by air convection with supplemental heat

The "Banda"

A maize drying practice current in the Gulf of Guinea consists of maintaining a wood fire alight in the storage structure to reduce the humidity relative to the ambient air. This is the only means of drying products under high rainfall conditions.

In the north west of Cameroon corn cobs, partially husked, are carried in baskets to the homestead and placed in a bed 30-40cm thick inside a structure called a "banda". The banda is the space above the ceiling of the kitchen (Figure 4.1). The base of the banda on which the cobs lie consists of an assembly of bamboo rails a few centimetres apart with an opening 60cmx60cm to provide access to the interior.

Drying is carried out by means of one or more wood fires which the women tend day

and night for at least two weeks. The cobs are regularly re-arranged to place the drier ones on top. After this period drying proceeds more slowly for a further two months based only on fires lit to cook meals. The cobs remain stored in the banda and are removed as and when needed by the family.

In the context of a subsistence economy the banda is perfectly convenient for the storage of relatively small quantities of maize. At present a considerable increase in maize production is observable in the countries surrounding the Gulf of Guinea for various reasons (liberalization of the economies and a shift from cash crops to food crops). In order to accommodate all the crop in the banda it is thus necessary to increase the depth of the bed of cobs to the detriment of the quality of the drying operation.

Figure 4.1- Traditional Granary or "Banda" in North West Cameroon (Source: Cameroon, A.V. Anthony)

4.2.2 Drying by air convection without supplemental heat

After the harvest, small quantities of maize are spread in the sun or the cobs are hung from trees, from poles or along verandas (Figure 4.2)

The "Tap"

The "Tap" is a drying structure found in high altitude (1800-2000m) regions in North West Cameroon which is not subsequently used for storage (Figure 4. 3). It consists of a platform raised above the ground and covered with a roof of thatch or corrugated sheet (better drying according to the peasants). Taps are frequently erected in the field to reduce transport distances. During the harvest, the maize is carried to the tap where the outer husk is removed, leaving only the inner husk around the cob. A preliminary selection is made to eliminate mar-formed or mouldy cobs. Then the husked cobs are spread on the platform in a bed 40-60cm thick and dried for about 6 weeks.

The tap is used simultaneously for storage and as a shelter (rain, meals, grading). This structure permits field losses to be minimised, reduces transport and defers carriage of the cobs until such time as roads are in adequate condition.

Figure 4.3 - The "Tap", North West Cameroon (Source: FAO, A.V. Anthony)

The "Bliva"

Traditional structures with walls in cylindrical form made of woven vegetable material are widely used, not only for storage but also for complementary drying of cobs when maize is harvested in the rainy season. The traditional structure used for drying and storage of maize in southern Togo, called a "bliva" is a special case where the careful arrangement of the cobs forms the walls of the granary (Figure 4.4). The platform which supports such a structure is raised 03100cm above the ground: this is called a "low granary". When the platform is raised higher (200cm) to permit a fire to be lit underneath, it is called a "high granary". The maize is harvested and stored at a moisture content between 22-25%. The husks are not removed and constitute a barrier against insect attack.

4.2.3 Improved structures

The maize crib

Experience at the African Rural Storage Centre (Ibadan, Nigeria) have led to the design of a narrow structure called a "crib" (Figure 4.5) where maize with a high moisture content (30%) harvested when ripe, may be stored conveniently. The width of the crib should not be more than 60cm in a humid climate to avoid fungal attack. The walls are made from grilles or vertical rails of wood, bamboo or palm frond stems (3-5cm thick). A roof ensures supplementary protection from the rain.

The principle of the crib is based on the drying capacity of the air which blows through the mass of husked cobs. It is best to treat the cobs with an appropriate insecticide before loading into the crib in order to protect them from insect attack.

Figure 4.5 - The maize crib (Source: FAO Bulletin No 66)

The hot air dryer

A hot air dryer has been designed by IRRI (Figure 4.7). With a drying capacity of 5001000kg of grain per day, it is made from local materials capable of being assembled

on the spot. Batches of freshly harvested cobs are dried to 20% moisture content, then shelled. Then the grain is dried to 13% moisture content.

This model, if made mobile, can be used to provide a rental service in order to optimise its use in the same area or village.

Figure 4.7 - IRRI-type hot air dryer (Source: CEEMAT, 1988)

The growth in production of maize in recent years has encountered a lack of drying capacity. Traditional drying structures which, as has been shown, perform relatively well, can accommodate the quantity to be processed. Grain which remains too long at a high moisture content risks attack from micro-organisms and consequent mycotoxin infection. (cf Chapter 6). Extension of new types of drying structure of higher capacity should be encouraged together with improvements in shelling and storage.

4.2.4 Comparison between traditional and improved structures

The mechanism of drying in the "bliva" has been studied by the University of Benin in

the context of a project financed by the CRDI (International Development Research Centre). As well as the two types of bliva, two other structures (granaries of woven vegetable fibres and the crib) have been studied to provide a comparison (Figure 4.6).

Observation of traditional granaries confirms their role as dryers. In effect, maize harvested at 18-25% moisture content is dried to 13% (or less) while this level is not achieved by cribs. The explanation commonly advanced of possible drying by movement of ambient air appears inadequate as the granaries are poorly ventilated. Another hypothesis has been put forward: the heat of the sun, stored within the mass of cobs contributes to maintaining a relatively stable temperature despite temperature changes in the ambient air. In parallel, differences in temperature are observable, firstly between different points in the interior of the granary and secondly between the inside of the granary and the ambient air. These temperature gradients cause air movement by convection in the interior of the mass of maize and thus correspond to a secondary drying mechanism (Smith et al., 1994).

Drying follows a sequence of 4 phases:

- **Phase of re-distribution of moisture between wet cobs and drier cobs.**
- **Phase where the mass of cobs at the base of the granary is drier than those at the top. Thus a positive humidity gradient is observable from bottom to top.**

- **In the third phase the maize is drier at the top than at the bottom. The mass of cobs reaches a lower humidity level.**
- **In the last phase humidity of the mass of cobs is raised by re-humidification from the ambient air.**

In addition, there exist horizontal and vertical air movements as a function of climatic conditions. When there is little wind, the mechanism for an exchange of air between the granary and the environment is due to convection of air in the heart of the mass of cobs. Air exchange happens essentially during day time when humidity is at its lowest. This mechanism is facilitated by passing smoke through the structure.

Contrary to the bliva, the crib has been conceived in order to permit the maximum exchange of air with the exterior environment. The wind assists drying during the day but the crib permits a greater uptake of humidity during the night. Because of this fact, the crib cannot dry maize to as low a level as the traditional granary in the tropical conditions of southern Togo.

Figure 4.6 - The four different types of granary in the drying/storage studies (Source: Smith and Kpakote, 1994)

Chapter 5: Grain storage

Between 60% and 70% of grain production in Africa is stored at farm level, generally for family consumption but also for sale and for seed. Storage methods which have evolved over many generations are often well adapted to local conditions.

The objective of all grain storage structures is to furnish a protection against deterioration due to rain and soil moisture and to provide a barrier against insects and vertebrate predators. In Africa, a considerable variety of post-harvest systems is found, depending on ethnic and agro-climatic zones. Therefore, the first part of this chapter will be limited to the presentation of harvest-drying-storage practices in the Sudan-Sahel regions of West Africa (Grolleau and Diop, 1987). Subsequently, techniques for improvement to traditional structures will be discussed. Finally, the specific cases of silos and cereal banks will be described.

A large number of publications have been produced on storage. This chapter is based on summaries from FAO Bulletins N 40, 53, 69 and 109 as well as on the paper

concerning the Togo Experience from Smith and Kpakot presented at the Accra Workshop.

5.1 Traditional storage techniques

Depending on the type of material used, granaries of plant material, usually well aerated, are distinguished from those made from clay with rigid walls impermeable to the external air. Construction or re-construction of granaries is done at harvest time.

5.1.1 Granaries of plant material

These "straw granaries" are typical of the Guinea or Sudan-Guinea zones. They are also found in dry zones such as the Sudan-Sahel zone. They are used for storing millet, sorghum and maize by a wide range of ethnic communities living in these zones (Figure 5.1).

The platform

The granaries are raised above ground level (from 25-30cm to 1m or more for smoke drying in the more humid regions of the south). The base of the platform, made from three or four beams braced at right angles, is supported on forked posts. The wood used should be resistant to termites, for example Prosopis africana, Burkea africana, Anogeissus leiocarpus, and Khaya senegalensis.

The granary walls

The cylindrical walls are made from plaited reeds, Andropogon guyanus or Guiera senegalensis, of bamboo cut into strips or of palm leaf veins. Among the Djerma of Niger and the Bariba of Benin the body and roof of the granary constitute the same conical assembly (Figure 5.2).

Figure 5.1- Traditional granaries of woven plant fibres (Source: FAO Bulletin N 69) (a) Traditional granary of the Mossi and Gourmantch (Burkina Faso), for storage of cereals

in ear. Platform on rocks. Granary of reed mats (plaited stems of Andropogon)

Figure 5.1- Traditional granaries of woven plant fibres (Source: FAO Bulletin N 69) (b) Mandingo granary entirely constructed from plant material, called a "Bountoung" Used for storing cereals in ear (south Senegal; north Guinea-Bissau).

The roof

The roof, typically conical, is of straw. It is composed of several layers of grass thatch (Imperata cylindrica = Akwa or Andongo) covering a frame of branches or bamboo fastened to the body of the granary with lianas. The fixed or semi-permanent roof may last up to ten years. Its life is reduced by frequent removal for extraction of grain through the roof. Some granaries are provided with lateral openings, inserted in the body of the granary.

Maintenance

Maintenance of a straw granary consists of re-tightening the reinforcing framework

and of replacing the roof thatch every two to five years. The increasing scarcity of traditional material (wood, reeds, straw) leads to use of substitute material of lower quality (less durable and more permeable) and changes the life span of the granaries. Frequently, plant material is replaced with clay (for example in the Djerma villages near Niamey).

Figure 5.2 - Djerma Granaries in Niger (roof and walls a single assembly composed of superimposed layers of millet stalks, reed mats and grass straw) (Source: FAO Bulletin N 69)

5.1.2 Clay granaries

These granaries, known often as "mud granaries" are characteristic of the driest zones (sahel and sudan-sahel). Located inside or outside dwellings, depending on local custom, they take varied forms: cylindrical, trapezoidal, oval or spherical.

The platform

For a square-section granary, the platform consists of a base of six large stones supporting, normally, three main beams across which are laid the wooden floor beams (figure 5.3). When the section is circular, the platform is based on either a circular bed of stones or a circle of stones around a central stone. Very short beams placed between the stones carry floor beams laid out as spokes of a wheel. These different types of platform are used for large granaries (8 - 12m^3 up to 60m^3 among the Hausa of Niger). For small granaries (0.5 to 2m^3) notably among the Gourmantch of Burkina, the platform is made on a base of 3, 5 or 9 stones in a circle. The height from the ground never exceeds 30cm.

The walls

The chosen clay comes from the banks of rivers or swamps or from termite mounds. Generally, it is mixed with chaff (fonio chaff) to reduce the effects of shrinkage. The Senoufo of the north of the Cte d'Ivoire use a mixture of clay and threshed rice panicles. A vegetable oil, Parkia filicodae or even karit, Butyrospermum parkii, are sometimes used as stabilisers. The mud floor (5 to 7cm thick) and the first layer of the

walls are placed in one operation without mixing straw with the mud. While this base layer dries (3 days) kneading of the mortar of clay and straw may commence (the wet mixture ferments for two to three days). Then the walls are raised in courses 7 to 10cm thick. The need to let successive courses dry can make the operation last several weeks. This explains the tendency to replace continuous mud walls with mud brick walls, built in a day but less resistant (Figure 5.4).

For square-section granaries which are relatively high (2.5 to 3m) ties placed across the walls rigidity the structure and serve as support or attachment points. Where the roof is fixed, an opening averaging 50 x 50cm is placed towards the top of the wall on the side most protected from the rain.

Among the Lobi and the Gourmantch of Burkina, the Dogon of Mali and the Somba of Benin, the store is divided into two, three or four compartments, permitting separation of different products.

Figure 5.3 - The different types of platform (Source: FAO Bulletin N 69)

The Roof

The straw roof overhanging the walls is constructed of the same materials as the granaries of vegetable material. It protects both the stored grain and the walls from rain and sunlight. Adequate materials are becoming increasingly rare so warehouses (flat roofed in corrugated sheeting) tend to replace traditional granaries in certain regions (around Tillabry in Niger and Slibaby in Mauretania). The use of the corrugated sheeting is explained also by its greater durability and its status as "an external sign of wealth" among some villagers. However, the sheeting, because of its high thermal conductivity compared with straw thatch, functions as a solar collector and does not ensure as good conservation of the stored products (Figure 5.5).

Maintenance

Maintenance of a mud-walled granary consists of rehabilitating the roughcast exterior coating, especially on walls exposed to rainfall, every four or five years. The roof thatch is replaced every two to five years. The mud brick granary needs a new exterior coating almost every year.

5.1.3 Preparation of granaries

Before storing the new harvest, certain precautions are important:

- **Remove all residual stocks**
- **Clean the interior of the granary. Among the Djerma of Niger the people thump the walls to make the termites and other insects drop off before sweeping them up. The Peulh (Fulani) of Casamance plaster the floor of the bamboo granary with a mixture of cow manure and the pounded leaves of Bournm (Hyptis spicigera).**
- **Combat pests by filling any cracks capable of sheltering insects with a mortar compounded of powdered insecticidal plants or chemical insecticides. Among the Lobi and the Dagari of Burkina Faso, millet or maize stalks are burned inside the granaries.**

5.1.4 Treatment of grain before storage

The transport of the ears in sheaves or bundles facilitates handling and examination of the crop before storage. If the residue of old stock can be consumed in two or three

months it is removed from the granary, threshed and kept in sacks in order to prevent mixing. Otherwise, the farmer constructs another granary for the new harvest.

Storage in ears

This practice is the most widespread whatever the type of granary since, according to family heads, "it is more economical and limits risk of wastage, given that the women sell off the grain in small lots". Another argument is that it permits better conservation, according to farmers.

Storage of chopped millet sorghum ears

The Dagari (Burkina Faso) practice this particular method of conservation for millet and sorghum. Millet ears are chopped in small pieces of 2 to 3cm before storing in bulk. Sorghum is threshed then stored in bulk without winnowing out the husks and panicles. This method seems to ensure better protection against insects in physically limiting their activity.

Storage as grain

Storage as grain is a recent practice in some zones of the sub-region and in some villages of Burkina Faso, Mali and Senegal (Moss), Marka, Bambara and Wolof people). This method of storage has assumed greater importance following environmental changes such as monetarization of exchange, decrease in vegetation and mechanization of threshing (Chapter 1). Among the Bambara, this practice leads to plastering the interior and exterior of the straw granaries to the detriment of the natural aeration of the granary. Similarly, the Wolof are progressively abandoning their straw granaries in Nguer and storing grain in sacks in houses or the new warehouses. This could lead to insect infestation and serious moulding (see Chapter 6).

5.2 Improved storage techniques

Traditional structures in local materials have the characteristics necessary to good conservation of harvested crops at relatively low cost. Nevertheless there are always

opportunities for improvement and above all where traditional materials are scarce or where the technical knowledge for construction is tending to disappear.

In order to improve waterproofing or combat rodents and insects, either existing granaries must be modified or new types of store must be introduced, based on industrial materials. These two approaches are difficult to implement due to the diffuse nature of the storage environment. A valuable technical improvement, even a small one, may seem unacceptable or too costly for the people involved. The farmer may be reluctant to adopt a new storage structure while the granary needs neither repair nor replacement. In addition, the lack of, or poor estimation, of costs and real benefits for proposed storage structures has led to promotion of technologies which were often inapt. These errors, over-estimated the level of losses to be reduced, the rate of refilling of stores (variable during the course of the same season), the price and demand of the stored product. On the other hand, aspects such as production, extension, and credit availability have been under-estimated. The following experiences in Togo and Benin are minmr modifications to the traditional structure which brought significant improvements.

5.2.1 Improvement to maize granaries in the south of Togo

Maize occupies a prime position among the food crops of Togo. As the cereal of greatest use in the Togolese diet, maize is used in some twenty local dishes. In the southern half of the country, maize has been harvested twice a year for a long time. In the northern regions maize is produced, to the detriment of sorghum, in one annual crop. In the cotton zones, maize has been grown in rotation with cotton for the last twenty years while in other areas it is usually associated with cassava or "nib".

A well maintained maize granary permits the farmer to profit from the rise in price from one crop to the next (175% to 325% between July-August and the next crop in May-June). Ninety to ninetyfive percent of the maize stored and consumed is produced by small farmers. This was taken into account in the application of low cost technical improvements based on existing structures. Intensification of production and the introduction of more modern techniques is envisaged for the future.

Technical description

As a result of research on the drying effected in the traditional "Bliva" granary (see

Chapter 4), Smith et al. (1994) arrived at the following conclusions. To achieve optimum drying of the grain (low moisture content) it is necessary to

- **maintain stable temperatures inside the granaries,**
- **reduce the grain surface exposed to ambient air, and**
- **reduce the uptake of moisture by the grain after rain or during the night.**

The smoke drying achieved during the first two weeks of storage and after each rainfall permits the redistribution of moisture in a homogeneous fashion. In order to allow the smoke to penetrate well throughout the mass of cobs after passing through the granary floor, a conical device was placed on the floor (figure 5.6). The ideal configuration would be to construct the floor with several adjustable vents. The vents would be opened during the day while the air is dry and smoke drying is possible, and closed at night when the air is humid. This configuration is difficult to achieve where the floor is made of tree branches. Studies should be carried out to devise an appropriate floor design.

Figure 5.6 - Granary fitted with a cone on the floor to improve smoke drying (Source: Kpakote et al, 1994)

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5.2.2 Improvement of storage in the south of Benin

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Maize is the principal food crop and dietary base for the people of southern and central Benin. Its cultivation extends to the north of the country where it constitutes the second cash crop after cotton. Maize is an important commodity traded commercially within the country and with neighbouring countries. Maize production was more than 271,000 tonnes in 1982 and reached nearly 460,000 tonnes in 1992 thanks to the efforts of agricultural development services.

Despite this dynamism in production and marketing, traditional storage practices remained unchanged and unadapted to the increased level of production. The appearance of new storage pests has aggravated this situation, leading to high losses (average loss rate rising from 10-15% to 30% for the first crop).

Improvement initiatives such as "Ditcher" silos, "Brooks" driers (1976) and "cribs" (1985) had little impact in rural situations. The project BEN/87/017, "Decentralized Storage Systems", executed with technical assistance from FAO has proposed some appropriate solutions (Afomasse, 1994). A base-line study was first carried out on the socio-economic environment of the "storage function" and a technical evaluation was made of the structures and methods of storage utilised. Subsequent improvements took into account the issues raised by the farmers, among which were:

- **the quality of timber used in the construction of the floor;**
- **the strength and durability of the structure;**
- **protection of the supporting posts against rodent ingress;**
- **the maize harvest period;**
- **preparation of the product before storage; and**
- **the treatment of the maize in husk with pesticides recommended by the pest control service(5).**

Parameters 2,4,5 and 6 were taken into account during trials on modified granaries.

Technical description of modified granaries

The circular granary of woven bamboo (BT) provided with a fixed straw roof and a window has been retained, to be modified in accordance with the needs of the peasant farmers. Two types of platform have been tested: the flat platform (height from ground to ceiling 0.80m) and the conical platform (height from ground to ceiling 1.20m and height from ground to base of cone 60cm) which permit good load spreading and better drying.

The three types of improved granary are:

- **BT2 - Diameter: 2m, Height: 2m, Storage capacity: 2 tonnes of cobs in husk.**
- **BT3 - Diameter: 3m, Storage capacity: 6 tonnes, conical central chimney in wood (60cm base diameter, 1.6m high). Figure 5.7**
- **BT4 - Diameter: 4m, Storage capacity: 10 tonnes, fitted with three wooden chimneys (50cm diameter, 1.6m high) udesigned to favour drying (Figure 5.8).**

Figure 5.7 - Adaptation of a chimney on the floor of a traditional granary (Source: Afomasse, 1994)

Figure 5.8 - Maize granary fitted with three conical chimneys in wood distributed evenly across the floor to improve air circulation (Source: Afomasse, 1994)

Technical results

It was observed that after three months the grain moisture content dropped to 15.3%, 15.8% and 15% respectively in granaries BT2, BT3 and the control granary (Table 5.1). At the end of six months, the grain moisture content was well below the safe storage level (about 1314%). On the other hand, in the 4m diameter granary (BT4) at the end of six months the grain moisture content was continually above 15%, despite the provision of cones to facilitate the passage of air. Increase of the diameter of improved granaries above 3m is therefore not to be advised.

Despite a systematic selection of cobs to discard those already mouldy, a significant level of moulding was observed due to storage for long periods at high moisture levels (Table 5.2). For the BT2, BT3 and traditional models the degree of moulding was small but could represent a considerable risk in the absence of monitoring and analysis. In the case of BT4 the level of moulding, above 10%, was definitely too high.

The evaluation of losses due to insects (Table 5.3) shows the significant effect of phytosanitary treatment associated with the preparation of cobs prior to storage in the improved granaries. Less than 1.5% loss in weight was found in the improved

granaries compared with 6.2% in the traditional granary.

Table 5.1- Evolution of grain moisture content (%)

Granary Diameter	At Harvest	After 3 Months Storage	After 6 Months Storage
2m	19.7	15.3	12.6
3m	20.0	15.8	13.6
4m	20.7	16.7	15.4
Control	18.9	15.0	11.7

Table 5.2 - Loss to moulding (% of grain mouldy)

Granary Diameter	At Harvest	After 3 Months Storage	After 6 Months Storage
2m	2.3	2.9	3.4
3m	3.4	5.7	5.1

4m	4.2	11.4	10.7
Traditional	2.9	3.0	3.2

Table 5.3 - Loss in weight due to insects (%)

Granary Diameter	**At Harvest**	**After 3 Months Storage**	**After 6 Months Storage**
2m	0.4	0.7	1.3
3m	0.2	0.6	0.9
4m	0.9	0.9	1.3
Traditional	0.6	1.6	6.2

(Source: Afomasse, 1994)

Socio-economic results

The cost of storage comprises the costs of construction, phytosanitary treatment and handling into storage. The cost/benefit ratio is the greatest value achieved in differentiating the sales of maize (Table 5.4)

Table 5.4 - Storage costs

Type of Granary	**Storage Cost**	**Cost/Benefit after 6 Months**
BT2	4,300 FCFA	2,125 F/tonne
BT3	3,150 FCFA	2,600 F/tonne
Traditional	4,100 FCFA	

Losses due to pests are considerably reduced thanks to use of a storage structure which performs well associated with a timely harvest, preparation of cobs prior to storage and phytosanitary treatment. The unaided spread of techniques for construction of improved granaries has started to develop in the project zone, a sign of the interest generated by the technique. The peasant farmers trained by the project are offering their services to other farmers on a commercial basis.

5.3 Silos

Traditional small, closed grain stores are used by farmers all over Africa. They include underground silos, walled silos and above-ground structures made from clay, often mixed with a strengthening material, notably straw or cow manure. They are found in regions where the hydrometric air conditions, at harvest time, easily permit grain moisture content to be lowered to 12% (or less) for good silo storage (Figure 5.9).

For 25 years attempts have been made to introduce "improved" silos, either to modify part of a traditional silo (floor or walls), or to replace a straw silo (Figure 5.10). Aboveground silos in timber, brick or concrete and underground silos present characteristics, of airtightness for example, adequate for good control of insects by fumigation. Nevertheless, the rate of adoption of improved techniques has often been feeble for various reasons (see the beginning of Part 2 of the chapter), notably: poor availability of construction materials, insufficient technical knowledge and the need for supplemental drying.

Two successful experiences, the spread of metallic silos in Swaziland and the

underground silo in Morocco are briefly described below.

5.3.1 The spread of metallic silos in Swaziland

Cultivated by all the farmers in the country, maize is the basic foodstuff of Swaziland. After drying in a crib or on house roofs, the whole crop is shelled before sale or storage on the farm, generally in metal silos. This constitutes a unique case in Africa, attempts to introduce this type of silo in other African countries having failed.

The first metal silos in Swaziland are described in reports of the Ministry of Agriculture in 1940 but their use did not develop until the 1950s. By the end of the 1960s they were made locally by small and medium-scale metalworking enterprises. It seems that no help in the form of training or subsidy has been given to these enterprises or to the farmers using the silos. It is perhaps worth noting that the rural communities are relatively wealthy and have easy access to materials such as galvanized sheeting. In 1971-72, 24.7% of farm holdings possessed an average of 1.3 metallic silos each, making a total of 12,400 silos in the country. in 1979, this estimate was increased to 15,000 silos. An inquiry in 1988-89 reported 30,000 silos (36% of holdings had 1.2 silos

each). In 1990 70% of farmers possessed a silo. Today in 1994, the number of silos is approximately 45,500.

Technical description

The construction of the silo is similar to that of local water tanks. Sheets of galvanized steel, 0.63mm thickness, are rolled and rivetted in rings to form the walls of the silo. Two sheets per ring are needed for a silo holding 2 tonnes. The sheets are fastened at top and bottom to form a hermetically sealed enclosure. Joints and rivets should be sealed with solder.

The silo is installed on a solid, level base, raised above ground level (Figure 5.11). Farmers place their silos in the shade of large trees, under shelters or inside their houses to avoid condensation problems. Well maintained silos last more than 30 years. Nevertheless, they are not considered permanent structures. This factor is of primordial importance for the Swazi farmer who does not own of the land.

The grain is filled through an opening 38 to 50cm in diameter at the top of the silo. A metal cover, overlapping the edges of the opening by 5cm provides a hermetic seal.

The extraction opening in the base is a descending tube, 15cm long and 14cm in diameter. The covers (filling and extraction) can be provided with security chains. The capacity of a silo varies between less than a tonne to 8 or 9 tonnes of maize grain. Those of one to three tonnes are most common.

Figure 5.11- Metallic silos in Swaziland

Grain fumigation

The major benefit of metallic silos is their resistance to rodent attack and the facility to control insects by fumigation. Farmers prefer fumigation to the use of insecticide powders. For fumigation, the filling and extraction openings are sealed with thick plastic sheet (an old fertiliser bag, for example) before fitting the metal covers. From the 1940s to the end of the 1960s, the fumigant used was carbon bisulphite in liquid form. Since 1972 phosphine has been adopted following a campaign of promotion and extension (Table 5.5). from 1972 to 1975 the Grain Storage Section has trained farmers in the safe, effective utilization of phosphine tablets. Moreover, in the absence of private enterprises in the market, it has established a distribution network and carried out demonstrations of the dosage and techniques for sealing the silos. This type of

action associated with advice on the installation and maintenance of silos has considerably improved the conditions for use of metallic silos in Swaziland.

Table 5.5 - Quantity of phosphine used for fumigation in Swaziland

Year	**Tablets PH3 Used**	**Quantity of Maize Treated** **(tonnes)**
1972-73	1,151	384
1973-74	2,975	772
974-75	10,024	3,341
1977	15,840	5,280
1978	146,880	48,960
1979	74,460	24,820
1992	293,320	97,440
1993	49,280	49,760

5.3.2 The underground silos in Morocco

Storage of grain in underground silos is an ancient technique practiced in many countries. In Morocco, many farmers prefer underground storage for conservation of their produce. It is estimated that storage capacity with this method totals about a million tonnes. This technique, used as well in Tunisia, in Egypt and in Sudan, is adapted to the rural context and to small holdings where soil conditions permit. The atmosphere, poor in oxygen, created inside the underground store, permits a reduction in insect attack. This constitutes a natural means of combatting pests as a substitute for pesticide products which are often difficult to procure (Bartali, 1994).

Technical description

Traditionally, the lining of the underground silo walls is of straw (Figure 5.12) or plastic (sheets simply stuck to one another). These practices can lead to penetration of soil water into the stored grain and considerable losses. In order to reduce these risks,

classic straw linings have been compared with a lining formed manually from polythene sacks, closely following the shape of the store (Figure 5.13). The study, financed by the USAID PSTC programme was carried out on the storage of hard wheat in 1.5-tonne stores for a period of 16 months. During the project, the farmers were invited to take part in different phases of the study: filling and emptying the stores, measurement and evaluation of losses.

Figure 5.12 - Underground silo lined with straw (Source: Bratali, 1994)

Figure 5.13 - Underground silo lined with plastic (Source: Bartali, 1994)

Results

- **The soil covering the silo protects the grain from fluctuations in the exterior air temperature. The temperature at the heart of the silo lined with plastic remained around 17C while the exterior temperature reached 45C. In the silos lined with straw the lack of air tightness led to greater biological activity within the mass of grain and the temperature could attain 30C.**
- **The relative humidity of the air in the silo, which was 53% before filling, increased**

rapidly a few days after filling to stabilize around 73 % (hydroscopic airgrain equilibrium) three months later.

- **The other parameters, CO_2 concentration, moisture content, volumetric weight and loss of dry weight are shown in the table below and highlight the better performance of the silo lined with plastic.**

Parameters measured according to type of silo lining:

Lining	**CO_2Conc. (%)**	**Moisture (%)**	**Weight/Vol (g/l)**	**Loss of Dry Weight (%)**
Straw	17	18	754	19
Plastic	13	12.5	674	3

- **Germination rate diminishes by 30% after 3 months in grain stored in straw-lined silos, while it remains at almost its initial value in grain stored in silos lined with plastic.**

The cost of using plastic sacks rose in 1987 to $25 for a silo of 1.5 tonnes. This investment, equivalent in value to a quintal of wheat, may save the farmer the

deterioration of several quintals of stock (moisture content, drop in germination capacity, nutritive and commercial values). Several farmers have already adopted the plastic lining. At each harvest the extension effort is continued: definition of the type of plastic to use, demonstration of the make up of the plastic sacks, techniques for filling and sealing the stores. Incentive measures have been adopted for decentralized storage on the farm such as negotiation with credit authorities to obtain flexibility in credit terms for crop finance.

5.3.3 Silos of clay reinforced with straw

Since 1987, another exercise, organized by the Department of Rural Engineering at the Hassan II Agronomic and Veterinary Institute in Rabat, has evaluated the performance of silos of clay reinforced with straw (Bartali, 1994). These silos are similar to storage structures used in China. In 1982, FAO highlighted the interest in such structures in countries with a tradition of construction in mud and straw for rural housing.

The structure is made from local materials. The wall is built from a mixture of clay and chopped straw in which are incorporated ropes of plaited straw arranged in a circle

with the objective of countering the internal pressure of the contents against the wall. Farmers also use vertical silos of reeds lined with clay with a capacity of 1 to 2 tonnes. The advantages of these silos are the low cost, the simplicity of construction and the good thermal insulation offered by the walls. Two pilot silos of 15 tonne capacity have been constructed in one coastal region and one continental region.

Technical description

The circular storage enclosure has a wall 0.45m thick, a height of 2.9m and a diameter of 3m. The clay and straw store is raised on a circular plinth 2m high provided with a door to control emptying. The base of the silo is conical to facilitate emptying at a rate of 6 tonnes per hour. The roof, of earth, straw or plastic is conical in form to permit better aeration and to shed rain water. The silo is filled through an opening high in the wall. At this level there are also grilles to improve the natural ventilation of the grain.

Results

Research on these structures has centred on storage of barley and soft wheat over periods of one to two consecutive years. These silos, cheap and durable, provide good storage conditions as they lend themselves well to fumigation, are characterised by interior temperatures lower than the ambient air and have a low rate of dry weight loss (4%).

5.4 Cereal banks

The last 25 years are remarkable for the appearance of the concept of "cereal banks" and the development of these structures. Following the serious droughts at the beginning of the 1970s it seemed necessary to put in place village-level structures, controlled by the villagers, in order to limit the situation of food insecurity and to complement the actions of the Cereal Authorities or to compensate for their shortcomings. This idea was based on two observations: i) the seasonal fluctuation in cereal prices (low price at harvest and high price when these stocks run down) which intervenes just before the following harvest; ii) the liquidity requirements of farmers which lead them to sell at low prices or to sell more than their real excesses which later obliges them to repurchase when prices are high.

The " village community granary" provides a means to buy at harvest time, to store and to sell when household stocks run low with the objective of:

- **maintaining a minimum stock at village level;**
- **provide a supply at lower cost in periods of shortage;**
- **offer a market for farmers wishing to sell produce at harvest time when prices are low.**

The first cereal banks, established in Burkina Faso between 1979 and 1983 were essentially designed for the food security of the village. During the 1980s the rapid development of cereal banks was assisted by national programmes and projects financed by international institutions and non-governmental organizations. These actions, which mobilized substantial resources, achieved varying degrees of success. Table 5.6 presents an estimation of the number of banks which is lower than the number actually created because of a fairly high rate of failure.

Eventually, cereal banks progressively accumulated functions of produce disposal and market regulation, much as commercial outlets for the Cereal Authorities (Gergely et al., 1990). However, because new national cereal policies, defined in the context of structural adjustment, have largely eliminated, or considerably reduced, the interventionist role of the Cereal Authorities, the cereal banks have found themselves

once more directly involved in the market without a privileged interlocutor. Despite this difficulty, cereal banks have provided, and always provide, groups of peasant farmers with the possibility of adapting themselves to new market conditions.

Table 5.6 - Cereal banks in sahelian countries (Gergely et al., 1990)

Country	**Number of Banks**	**Equivalent Tonnage**
Senegal	240	4000
Mali	400	4,700
Burkina Faso	800	6,000 -7,000
Niger	370	4,800
Mauritania	25	-
Chad	500 -1,000	-

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Chapter 6: Post-harvest losses

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There are numerous publications in FAO dealing with this subject, in particular FAO Bulletin N 53 - Processing and storage of foodgrains by rural families (1983); FAO Bulletin N 93 - Post-harvest operations and management of foodgrains (1992) and FAO Bulletin N 109 - Grain storage techniques (1994). This chapter is based on these publications.

Traditional means of grain storage at village level are the result of the evolution of ingenious empirical systems. Through the generations, farmers have developed their own techniques, often very elaborate and masterly (see Chapter 5). Apart from the storage function, the granaries and other traditional structures are designed to reduce to a minimum the losses caused by the principal enemies of the harvest: insects, moulds, rodents, and fire. Proliferation of insects and moulds depends on climatic factors (humidity, temperature and the interstitial environment of the grain); the presence of rodents, termites, fire and theft is linked to the techniques of construction of the granary (location, materials and type of architecture). Evaluation of the wastage through storage in traditional granaries has only been subject to precise measurement

recently. Data available is fragmented and cannot be extrapolated to represent a complete country or sub-region (Table 6.1).

Table 6.1 - Rate of loss through storage of millet and sorghum in traditional granaries in Africa

Country	**Product**	**Loss (%)**
Senegal	Millet in ear	2.2
	Sorghum in ear	5.3
	Sorghum as grain	9.5
Northern Nigeria	Sorghum in ear	4.0
	Sorghum as grain	4.0
	Mali in ear	2 to 4
Niger	Millet in ear	10.1
	Millet as grain	3.4
Burkina Faso	Millet in ear	6.9
	Millet as grain	8 months storage

6.1 Waste and loss

6.1.1 Insects

Although peasant farmers find it difficult to estimate losses caused by insects, on the other hand they can precisely identify the infestation period. The FAO project in Benin studied interest in how villagers perceive and estimate losses due to insects according to several criteria: quality of conservation between varieties of cereals and period of infestation. Generally, it can be affirmed that insects cause the greatest losses (Boxall, 1994).

In the Guinean zone of Benin, Togo and the Cte d'Ivoire, high humidity, even during the short dry season, favours development of the principal storage pests: Sitophillus spp (weevils) and Prostephanus truncates (Larger Grain Borer). According to information received from the farmers, losses caused by insects after six months storage are 2% to 3% for husked maize cobs. To that must be added losses (up to 15%)

in threshing from grains spoiled by insects after three months storage. The appearance of the Larger Grain Borer has raised doubts about the effectiveness of granaries and traditional techniques.

In other zones of the sub-region, climatic conditions do not favour the proliferation of common insects during the first five months of storage (December to April). In May, higher humidity provokes the appearance of insects. Species observed on sorghum and millet in ear are Corcyra cephalonica (Rice Moth), Rhizopertha dominica (Lesser Grain Borer) and Tribolium castenum (Rust Red Flour Beetle). The wastage caused by the Rice Moth is small since it is limited to the upper 20cm of the stock.

6.1.2 Moulds

The development of moulds is linked with specific atmospheric conditions (temperature and humidity) as in the southern zones bordering the Gulf of Guinea where humidity is very high. In the rest of the sub-region the climate does not favour the growth of moulds, and granaries installed on platforms are conveniently isolated from the soil. Except where water infiltrates through a defective roof, farmers do not

report any cases of moulding in their granaries.

In the region of Mopti in Mali and Ayorou in Niger, serious losses have been revealed following the transfer of humidity through the mud floor of granaries, the only screen between the soil and the grain. Where the storage of maize cobs, millet or sorghum is on the ground in the new warehouses (among the Guidimakha in Mauritania and the Borgou in Benin) moulds appear in the lower layers of the stock.

The case of mycotoxins

Mycotoxins are highly toxic metabolites produced by various moulds. The toxicity of mycotoxins causes chronic illnesses affecting the nervous system, the cardio-vascular system and the digestive and pulmonary systems. Certain mycotoxins are carcinogenic and others are immunodepressives (lowering resistance to disease), (Cooker, 1994).

The principal mycotoxins are produced by certain species of Aspergillus, Fusarium and Penicillium. The worst are aflatoxins including the Aflatoxin M1 in milk (produced by A. flavus and A. parasiticus), Ochratoxin A (A. ochraceus and P. verrucosum), Zearalenone and Deoxynivalenol (F. graminearum) and Fumonisins (F. monoliforme).

6.1.3 Rodents

For most villagers, the presence of mice in granaries is almost permanent. Present in straw granaries, they equally find their way into clay granaries through the roof or by making holes in the base and can thus cause the granary to collapse.

In the village of Missira (Senegal) rats have appeared in large numbers after some ten years. They cause serious wastage of the stored produce (as much as 20% loss per year) both by their consumption and faecal contamination.

6.1.4 Theft and fire

The increasing importance of theft is a consequence of the lack of food after several years of drought. The fear of theft is a factor determining the choice of storage technique. Farmers increasingly see themselves forced to completely thresh the whole

of their crop to store as grain in the security of a warehouse. In the region of Tillabery (Niger) some people prefer to store paddy in their huts or shops, even if they know that this method is not favourable to conservation.

Straw granaries are subject to fire risk and are therefore constructed away from dwellings. In Missira (Senegal) villagers have adopted bulk storage in clay warehouses with metal roofs for fear of fire, even if this type of storage is less effective.

Under socio-economic pressure granaries may be built near habitations or in improvised locations to the detriment of storage conditions and despite the fire risks.

6.2 Techniques for control or preservation

Numerous studies during the last 20 years have shown that in traditional post-harvest systems, losses are generally maintained at a low level, around 5%. This value constitutes an optimal threshold since the evolution of storage systems does not always offer an adequate protection for produce.

6.2.1 Activities in preparation for storage

As has been shown in Chapter 5 (Paragraph 5.1.3), activities in preparation for storage (cleaning the granaries, destruction of infected residues, selection of healthy ears at harvest) permit a substantial reduction of insect attack. Also, hygiene is absolutely necessary to ensure effective control with chemical products.

6.2.2 Varietal selection

Certain high yielding varieties are often more vulnerable to insect attack than local varieties which are naturally selected for aptitude for storage and resistance to insects. In agronomic research, selectors take into account factors linked to production (yield, drought resistance) and to use (processing and consumption). Research into varieties resistant to insects is perhaps judged to be secondary since control may be achieved with the aid of insecticides.

6.2.3 Pesticides

This term, habitually synonymous with conventional insecticides, is applied also to fumigants, local insecticides and biopesticides. Pesticides are considered as the most effective technology for protection of stored products. They have gained the approval of peasant farmers, they are adaptable to storage systems and need little effort in application. Moreover, they are economically profitable: the value of grain saved representing 10 to 25 times the cost of the insecticide. More important benefits may be obtained in zones infested with the Large Grain Borer. However, despite the employment of pesticides, considerable storage losses are still reported.

Chemical insecticides

The most common insecticides used in grain storage are the organophosphorous compounds pirimiphos methyl, chlorpiriphos methyl, fenitrothion and malathion. In general they are very efficacious against common pests, they are less so against the Bostrichidae or Grain Borers which include the Larger Grain Borer. Synthetic pyrethroids such as deltamethrin and permethrin are used against this insect, either alone or together with organophosphorous compounds.

The utilisation of insecticides unsuitable for the system of storage is a major problem. Where maize is stored on the cob because of lack of space or labour, the farmer is forced to shell it just before consuming or selling it. However, to prevent insect infestation the treatment should be applied to the grain immediately after harvest. Sometimes, the use of insecticides can be dangerous. Farmers are using, fungicides, acaricides and insecticides in powdered form, for stored foodstuffs, which should be reserved for the protection of seed, for example HCH, Thioral, Thirame or, worse, Dieldrin and Endrin.

In the face of this situation several actions should be taken:

- **Inspection**

  Inspection methods permit the detection of indicators or levels of infestation corresponding to application of a treatment in order to avoid serious losses and wasteful, superfluous insecticide treatments.

- **Extension**

  Efforts at information extension on pesticides are undertaken principally in the zones dedicated to cotton. Extension services normally advise the

employment of insecticides recognized as efficacious but less noxious, notably pirimiphos methyl. It is recommended to invest in training commercial pesticide distributors on safety and use of pesticides for storage, who can then provide this information to the farmers. Moreover, improvement of the labelling of pesticides (correct formulation and mode of employment) should be done. Labelled packages should already be in the appropriate size in order to avoid having distributors subdivide them into smaller packages, which is a dangerous procedure.

- **Distribution**

For some time, public bodies were able to support the provision of inputs and to provide advice on their utilization. Economic reform programmes have reduced budgets and have led state bodies to retire from input distribution with a reduction in extension services, leaving in their place the private sector. It is essential to ensure timely distribution of sufficient quantities of recommended insecticides in order to limit the inappropriate use of certain other products.

Legislation

> Few countries have proper legislation permitting the control of the composition of phytosanitary products, their importation and their marketing. In most cases legislative measures are non-existent or not accompanied by the means of enforcement.

The range of insecticides available for stored grain is limited and introduction of new insecticides is slow. The application of insecticides to food products is regulated by the International Commission of the Codex Alimentarius. New chemical products thus have to pass toxicological and environmental tests. The market being relatively restricted, manufacturers do not show much inclination to develop new products.

Fumigants

Another risk with pesticides is the resistance that pests develop in response to chemical products. The phenomenon of the resistance of insects to the fumigant phosphine is more serious than resistance to insecticides because there is no other alternative for fumigation on a small scale.

Fumigation with phosphine is attractive for farmers because its formulation as tablets

permits easy distribution and simple application. However, the dangers represented by inappropriate packaging, high toxicity and risks of re-infestation are often underestimated. Airtight enclosures should be adopted to achieve completely safe fumigation. Metal or plastic drums or double-thickness plastic sacks, silos of non-porous cement, of metal or of baked earth represent a number of possibilities. The debate on the use of fumigants continues - it seems unrealistic to prohibit their use. Training farmers and distributors is necessary.

6.2.4 Control of mycotoxins

To prevent contamination by mycotoxins, it is necessary to bring stored products down rapidly to safe moisture content and to maintain that level, to combat pests and rodents and to reduce physical damage to the grain.

A strategy for control of mycotoxins should include the following actions and should be applicable by semi-qualified operators:

- **identification of the nature and extent of the problem,**

- **introduction of improved methods of handling and quality control,**
- **use of detoxification procedures**
- **establishment of work groups, including representatives of the health, agriculture and livestock sectors, on the dangers presented by mycotoxins, and**
- **support and training of national laboratories.**

Up to now, the successful implementation of such a strategy has been achieved by the Mycotoxin Centres in Pakistan, Bangladesh and Philippines and partially in Zambia. The establishment in Africa of Regional Work Groups on mycotoxins should be envisaged in order to determine the needs in terms of studies and the strategy to follow as a function of the needs.

6.3 Alternative techniques

Concern relating to the cost, availability, high toxicity and resistance to insecticides has encouraged research into alternative compounds.

6.3.1 Local insecticides

Peasant farmers have traditionally used a wide variety of local products with insecticidal properties: minerals, oils, and vegetable extracts from plants and trees.

Minerals

Minerals such as sand, chalk and ash are used on grain as a physical obstacle to the insects. Large quantities are needed, from 10g per kilo of grain up to 50% of the weight of the grain to be treated. In the conservation of Nib in large sealed jars, these products are employed in finely powdered form to fill interstitial spaces and eliminate the air (oxygen). This method of preservation of leguminous grains is common among the Hausa (Niger), the Bwaba (Mali) and the Dagari (Burkina Faso).

Very fine powders are more effective as insecticides although difficult to produce locally. Industrial processes are needed to control the effect of powdery sub-products on the workers. These inert, absorbent or dehydrating powders act on the cuticle of the insect, causing loss of body fluids, desiccation and death. However the action of these powders is ineffective unless the microenvironment of the grain is dry enough to

permit rapid desiccation.

Oils

The effect of oil on the grain is complex. Certain oils form a physical barrier, others are repulsive while others have true insecticidal properties. Their use is costly because of an application rate of 5 to 10ml per kilo of grain and this can affect germination. The use of oils is a promising alternative, and also effective against borers, but methods of oil extraction and grain cleaning will have to be improved.

Plant products

Farmers use products of vegetable origin (leaves, stems,, roots, flowers, fruits) against storage insects and termites. Among the plants whose use has most often been reported is Hyptis spicigera. This is used for the protection of legumes in pod (nib, voandzu, groundnut), in the form of powder on cereals or as a rough cast lining in granaries.

The neem (Azadrichita indica) is the most popular and promising vegetable insecticide. Extracts of neem and products derived from it have even been manufactured and marketed as insecticides. Other promising materials include sweet flag (Acorus calamus), wormseed (Chenopodium ambrosioides) and peppers (Piper spp.) with repulsive aroma and taste.

Other plants have been surveyed but their scientific names have not been identified - in particular, among the Dagari of Burkina Faso, a plant called "Napkaw". The stems and the dried and pounded leaves are reduced to a powder and mixed with ash for support. Application is made by successive layers on stocks of sorghum, rice and groundnut. Napkaw, whose pods resemble those of soya beans is known among the Lobi of Burkina Faso under the name of "Tingtingou" or "plant which kills flies" and is used for protecting animals.

Among the Gourounsi of Burkina Faso the flowers of Cymbopongo giganteus are used against insects and among the Gourmantch a plant called "Jumfani" protects the nib in pod.

The local production of natural insecticide materials has several beneficial effects:

- **it assures independence from national supply systems,**

- **it reduces the cost of acquisition of insecticides, and**
- **it creates local employment for the collection and transformation of the raw materials.**

Despite the wide interest, few institutions have occupied themselves with the production, collection, processing and application of these compounds. The following information is still needed:

- **the quantities needed for large quantities of natural materials;**
- **cost of harvest and processing;**
- **risk of toxicity and soiling with repulsive odours;**
- **cleaning the grain before treatment;**
- **availability of the product at the right time of year; and**
- **differences in the active ingredient in the plant depending on season and production system.**

6.3.2 Growth regulators

Growth regulators are compounds which act on the biochemical processes of insects and prevent their development. The modes of action of growth regulators vary. Some inhibit production of the chitin necessary to the formation of cuticle. Others disturb the production of hormones controlling metamorphosis and development and control is thus slow. Species-specific, they are not neurotoxic and do not risk being harmful to humans or other vertebrates.

Although known and available on the market, the development of growth regulators has been slow. It is too soon to suggest that they will become viable alternatives. Registration procedures for each application are long and costly which reduces their competitivity in terms of cost.

6.3.3 Biological control

Biological control consists of introducing a natural predator specific to a pest with the objective of destroying it in a lasting manner. Biological control, which is still rare, requires little or no recurrent cost and little effort on the part of the farmer. It has been tried in Africa for control of the Large Grain Borer, using Teretrisoma nigrescens,

its hereditary enemy originating in Central America. The results of this means of control of the Large Grain Borer in Kenya, Togo and Ghana are not yet known but are in the course of evaluation (monitoring and impact analysis).

6.3.4 Perspectives

The control of storage pests needs a specific evaluation for each particular situation.

Traditional methods of combat as well as pre-storage practices reduce insect infestation significantly. Use of natural insecticides should be encouraged actively, applying more field research and assistance for the development of technology for extraction and processing of natural compounds. However, it will be necessary to estimate as accurately as possible the cost of using these alternative compounds (development costs, toxicity and registration procedures).

The employment of conventional insecticides, already in use for some time, should be improved (training, supply), in order to avoid problems such resistance of insects to chemical products. This activity, up to now developed by the public sector, will need

greater involvement of the private sector in future years.

Lastly, the introduction of new storage structures and the employment of pesticides should be technically valid and socio-economically acceptable. This will be best accomplished if the active participation of the peasant farmers is sought at every phase in the process of technology development.

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Chapter 7: Grain processing

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7.1 Hulling and milling local grain

In Africa, rural dedicate a great deal of time and effort to processing local cereals such as millet and sorghum. In the countries where these cereals were traditionally the basic foodstuffs of the people, an increasing tendency noted in urban areas is to substitute cereals such as wheat and rice which are already processed and ready to use. The drudgery of the task and the lack of services to hull local grain in urban areas are the principal constraints which explain this phenomenon and which create the risk, if nothing is done, that traditional cereals such as millet and sorghum will be marginalized or might even disappear.

7.1.1 Sorghum and Millet

If a longitudinal section of a sorghum or millet grain is examined, three principal parts may be identified: i) the pericarp (the external layer of the grain); ii) the endosperm (the farinaceous albumen, rich in starch) and iii) the germ (or embryo, development of which gives birth to the new plant).

Figure 7.1- Longitudinal section of a cereal grain (Source: Franois, 1988)

The pericarp, also commonly called the "bran", consists mainly of fibre and sometimes unpalatable compounds. Thin pericarps have a tendency to adhere firmly to the kernel, contrary to the thick pericarps and this makes hulling difficult.

Some sorghum grains are characterised by a coloured layer (brown to violet) called the testa, immediately under the pericarp. This coloration is associated with a heavy concentration of polyphenols (also called tannins) which inhibit the capacity of the human organism to digest the proteins in the grain. It is for this reason that in the traditional hulling process the operation is maintained until the testa is completely removed.

The endosperm comprises a glassy (or vitreous) portion and a farinaceous portion. The relative proportions of these two components determine the texture of the grain (an important characteristic for the quality of the flour produced from it). The proportion of vitreous endosperm determines the capability of the grain to withstand traditional pounding without being reduced to a powder. The higher this proportion, the less cracking there will be during hulling with a pestle and mortar.

The germ contains, essentially, the fat and protein. Among some sorghum cultivars, the germ is firmly anchored in the endosperm, making its extraction difficult.. Although flour containing a high proportion of germ has poor keeping quality (it becomes rancid)

it is much more nutritious.

With cereals such as wheat or maize the bran may be removed by a simple milling followed by sieving the flour. In the case of millet and sorghum, on the other hand, such a process is not possible. The pericarp of a millet or sorghum grain has the peculiarity of disintegrating into fine particles when the grain is crushed. These particles of bran are then impossible to separate from the rest of the flour by sieving. For this reason, if it is necessary to remove the bran from millet or sorghum grain a separate hulling process is required.

The objective of hulling is to remove the external layers which contain mainly fibre and sometimes tannins, presence of which in the flour affects the cooking quality and the taste and texture of the food. Hulling, therefore, should effectively remove the complete pericarp and testa, at the same time minimising loss of endosperm and germ. The degree of hulling needed for this optimal result varies from one type of grain to another and even between varieties of the same type (Table 7.1).

The process of hulling still most commonly used in Africa is to pound the grain in a wooden mortar. This is a laborious task which is generally incumbent on the women. Usually, the grain is moistened (about 50g of water per kg of grain), before pounding in the mortar, then dried in the sun and winnowed to separate the bran.

In 1981 - 82 the regional project FAO/RAF/045/DEN, in collaboration with ICRISAT, mounted a study on traditional methods of grain hulling and milling in Mali (Vanek, 1986). For hulling, some results of the study are presented in Table 7.2.

Table 7.1- Relative proportions of pericarp, endosperm and germ in various types of sorghum and millet grain (Bassey and Schmidt, 1989)

Grain	Pericarp %	Endosperm%	Germ %	Theoretical Yield %
Sorghum - Thick Pericarp	6.0	84.0	10.0	94.0
Sorghum- Thin Pericarp	3.0-5.0	90.0	5.0-7.0	95.0-97.0
Millet - Large Grain	7.0	76.0	17.0	93.0
Millet - Medium	7.5	75.0	17.4	92.5

Grain				
Millet - Small Grain	10.6	74.0	15.5	89.4

Table 7.2 - The effectiveness of traditional methods of manual grain hulling in Mali (Vanek, 1986)

Product	**Capacity (kg/h)**	**Hulling Yield (%)**	**Specific Energy Consumption* (kJ/kg)**
Sorghum	4 to 6.5	65 to 75	40 to 70
Millet	7 to 13	55 to 75	20 to 40
Maize	9	60	30

*** Specific energy consumption was calculated from the time taken for pounding multiplied by the average power output of a human being, estimated at 75 Wan.**

7.1.2 Description of the technique

In order to better understand the comparison of different methods of hulling, it would be worthwhile to recapitulate the definition of three parameters often used:

- the **hulling yield** measures the degree of hulling which the person supervising the operation, (that is, the woman), judges acceptable as an indication of the completeness of the operation; this is the proportion (as a percentage of the weight) of hulled grain compared with the initial weight of grain prior to hulling. Thus, for example, for the traditional method of hulling sorghum in Mali, the hulling yield is 65 - 75 % (Table 7.2).
- The **theoretical yield** is the proportion of grain (as a percentage of the weight) which represents the optimal consumable portion or the proportion acceptable by the consumer. For the sorghum with a thick pericarp, for example, the theoretical yield is 94% (Table 7.1).
- The **hulling efficiency** (in %) integrates the two previous parameters. It provides an objective measure of the efficiency of the operation and a comparison between

equipment and types of grain in terms of hulling performance. It is given by the following formula:

Hulling Efficiency (%) = 100-RT /100-TE 100

RT = Theoretical Yield

TE = Hulling Yield

7.1.3 The Engleberg-type huller

Many initiatives have been tried to add more value to local cereals in mechanizing the processing, notably hulling. The "Engleberg" type hullers were introduced first and are still the most commonly used in Africa for hulling cereals. These machines have the advantage that they are simple and robust. That, in turn, has favoured local manufacture and a greater availability of repair parts in the marketplace.

Although conceived for a continuous function, the machine is generally used for hulling

small batches of about 5kg on a rental basis. Therefore, the machine is not used to its full capacity, and the specific energy consumption increases with the small batches hulled (Table 7.3).

The grain is often moistened by adding water just before hulling. This has the effect of softening the surface of the grain and facilitating detachment of the pericarp under the actions of friction and pressure inside the machine. Typical hulling yields of wet grains are of the order of 6570% which correspond to the levels obtained by manual hulling in a mortar.

Table 7.3 - Performance of Engleberg Hullers m Mali (Vanek, 1986)

Product	**Capacity (kg/h)**	**Hulling Yield (%)**	**Cracked Grain (%)**	**Specific Energy Consumption (kJ/kg)**
Sorghum	174	71	30	124
Millet	155	70	14	111
Maize	198	67	90	58

7.1.4 Abrasive hullers

The operating principle of these hullers is essentially based on the friction between the grain and an abrasive surface, which has the effect of removing the external coat of the grain. The friction of grain against grain also contributes to the hulling to a certain extent. The abrasive surface may be stationary or rotating.

Stationary cone hullers

In the case of the huller produced by FAO (Foundries of the Western Workshops), the abrasive surface is a stationary cone. The grain is moved and rubbed on the cone through the action of rotating rubber vanes. The capacity of the machine varies between 200 and 275 kg/in, for a hulling yield of about 78 % and a specific energy consumption of 75-95kJ/kg. The machine includes a system for separating the bran and hulled grain. Unfortunately, this huller which was introduced in Senegal in the 1970s for hulling millet and sorghum is too complex for use in a rural environment. This explains,

perhaps, the fact that its use did not spread throughout the country.

Abrasive disk hullers

Abrasive disk hullers are simple in concept. They consist essentially of a mild steel casing with a rounded base, inside which is a rotating set of abrasive disks fastened on a shaft (Figure 7.2). In operation, the quantity of grain loaded up to the level of the shaft depends on the volume of the casing. The friction between grain and abrasive disks and between the grains themselves brings about the removal of the pericarp.

The first prototype of the abrasive disk huller was introduced in the mid-1970s in Botswana, Senegal and Nigeria for research station trials with the assistance of the International

Development Research Centre (IDRC). This first machine, then called the "PRL Huller" was conceived for continuous operation, with a capacity varying between 250 and 500kg/h depending on the type and variety of grain. The minimum quantity of grain that could be hulled was 20kg.

The **PRL/RIIC Huller** was a modified and improved version of the preceding one. It was manufactured locally and spread widely among the private millers in Botswana.

Figure 7.2 - The abrasive disk huller or PRL/RIIC huller (Source: UNIFEM, 1988)

7.2 Case study on rice hulling in Mali

The region of Sgou is among the most productive rice producing regions in Mali. Since the 1970s the Office du Niger (Niger Valley Development Authority) has been charged with promoting irrigated rice cultivation and intensification of production (double cropping). Production more than tripled between 1981 and 1994 (Table 7.4). The office du Niger had a monopoly in the rice sector up to 1984. At present, 44,000ha (30-50% of national production) are under the control of the Office. The producers (about 10,000, each cultivating an average of 4ha) are not obliged to sell their paddy to the Office.

Since 1979, The Netherlands had assisted the Office du Niger through Project ARPON (Improvement of Peasant Rice Cultivation in The Office du Niger) with the objective of increasing production and productivity. In 1989, Project ARPON, evaluating the needs of the villagers, gave support to the Female Economic Interest Groups (GIEF) in

the mechanization of rice hulling. This project, entitled "Action Hullers", was to serve as a motor of socioeconomic development in the region in creating new employment opportunities and income for the women and in improving the financial situation and status of the GIEF. In effect, the mechanized hulling permits women to add value to their produce, in selling it as rice rather than as paddy, as well as saving time and avoiding the drudgery of manual pounding. Also, a by-product, the bran and pulverized hulls can be used to feed animals.

Table 7.4 - Rice production levels in the "Office du Niger" Region

Years	Area (ha)	Yield (kg/ha)	Production (tonnes)
1980-81	35,589	1,977	69,290
1984-85	38,154	1,680	64,086
1989-90	44,251	2,411	106,593
1993-94	45,442	4,900	222,665

7.2.1 Introduction of technology

The project team. in collaboration with the interested users chose the VOTEX huller from among existing models for various reasons:

- **its low cost compared with other hullers;**
- **its ease of use, maintenance and repair; and**
- **the possibility of local manufacture by the Farm Machinery Assembly Workshop (AAMA).**

The introduction of this equipment was made possible thanks to the "Village Development Fund which provided credit at 9%, repayable in two years.

The project was organized through several groups:

- **the work teams (2 or 3 women sometimes assisted by a machine operator) charged with the hulling, the maintenance and the administration of the equipment. These teams received training in operation and maintenance and a remuneration of 7-10% of gross revenue, and**

- **the management committees trained to keep the accounts and to administer and organize the production teams.**

During group meetings, general questions (working hours, price of the services, results of the activity, re-investment of funds) were discussed among all the women of the group.

7.2.2 Evaluation of results

Since the start of the project in 1989, 78 huller units have been installed in 76 villages. The operation has processed 10,000 tonnes of rice with total net profit of US$133,000 (US$1 = 300FCFA) for the 76 villages. However, not all the units have achieved the same success rate. In 1992, only 56% of the huller units had been able to pay off the whole of their debt while 50% of the units had been obliged to cease hulling activity either temporarily or permanently.

Hulling appeared to be a profitable activity at the start, however profitability declined rapidly afterwards for various reasons:

- rice producers, seeing the financial success of the GIEF in 1989 bought their own hullers, thus becoming major competitors. The GIEF as a collective body, found it very difficult to react in a rapid and direct manner to the competition.
- the technical choice of the competitors was the hullers made in India and China (Engleberg type with cast hulling element) with higher capacity (300 to 400kg/h) producing a whiter rice more appreciated by consumers. In comparison, the VOTEX hullers has a capacity of 150kg/h and a hulling yield of 81 to 87% but it produces brown rice (= not white) whereas the preference of the consumers os for white rice. The advantage of the machine's mobility was not exploited in offering a door-to-door service.
- the maintenance and repair service should have been provided by the technicians of the Office du Niger. In fact the latter gave priority to the private hullers with whom they had signed service contracts.
- the competition between rental services caused the price of hulling to drop by half between 1989 and 1993. At the same time the price of fuel and repair parts was increasing. This situation led to a serious loss of motivation among the women of the GIEF.
- the lack of a spirit of enterprise on the part of the GIEF sums up the difficulties encountered in "Action Huller". In practice, the majority of women did not react as "producer groups" (joint responsibility and collective ownership) but as

individual consumers considering the huller as a simple domestic tool. Taking little interest in the development of the activity, the management or the administration, the members of the GIEF could not adapt to a new competitive situation (adjustment of price, response to consumer need). (Zoomers, 1994)

7.3 Case study on sorghum porridge

In the Sudan-Sahel sometimes, sorghum is consumed by thirty to forty million people in the form of "porridges", fermented, neutral (Cameroun and North Togo), acid (Burkina Faso) or alkaline (Mali). The name most commonly used in the Sahel for these porridges is "to".

The quality criteria demanded by the consumers are:

- **Texture: the porridge should be firm but should not stick to fingers or teeth.**
- **Conservation: the porridge should maintain its texture until the following morning without sweating.**
- **Colour.**

- **Taste: this varies by ethnic group and seems partly masked by the taste of the accompanying sauce.**

The conclusions of the study on the quality criteria for porridge are:

- **Vitreosity and hardness have no influence on the texture of the porridge.**
- **The lower the ash and protein content and the higher the starch content in the hulled grain, the firmer the porridge.**
- **Hulled grain with about 1% mineral matter content gives a firm enough porridge.**
- **70% of the texture of the porridge is due to the characteristics of the starch (solubility and swelling at 85C, amylose content). A porridge is as firm as the amylose content is high.**

Contrary to the local varieties of sorghum, the improved varieties with good agronomic qualities (yield, resistance) produce a porridge which is often soft and unattractive to consumers.

An African regional standards project has been drawn up by the Codex Alimentarius FAO/OMS. For sorghum grain (entire or hulled) the level of moisture, ash and protein, cellulose and fat, impurities and hulling, conditions of hygiene and packing have been fixed. The application of these standards requires a serious effort on the part of the

countries and operators concerned. For sorghum flours the ash content should be between 0.9% and 1.5% (dry matter) and the granularity below 0.5mm for a fine flour or 1mm for a medium flour. The application of these standards is not obligatory but it does permit the processor and user to characterize and position the product.

Since the devaluation of the CFA Franc, the consumption of local cereals has grown in urban areas and the quality of this supply should be encouraged. The three criteria which should be respected at the processing and milling stage are the choice of varieties, the cleanliness of the grain and the granularity of the milled product. The various institutes or food technology laboratories directly concerned with processing cereals have a role to play in the promotion of the concept of quality through training, price incentives and choice of processing equipment.

In the marketing and distribution stages, other quality criteria intervene, in particular the packaging and conservation of the products, subjects not treated here. At markets and in certain shops traditional cereal products are found, packed in plastic sachets, sometimes with instructions for their use. This important development should be followed up.

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Chapter 8: Grain Quality

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The technical quality of a grain is the link between the characteristics of the grain (texture of the endosperm, size and shape, thickness of the pericarp) and its behaviour in processing (hulling or milling). These differences in technical quality are often raised as issues when new varieties selected by agronomists for high agronomic potential give poorer results on processing than traditional local varieties.

The quality of cereal products has different implications depending on the person's role in the production chain, from the producer right through to the consumer (Faure, 1994):

- **Traders and stockists want dry, clean grain, neither infested nor damaged.**
- **Millers want clean grain in homogeneous batches, not too hard for grinding and giving a high yield of milling products.**
- **Processors want hulled or broken products of homogeneous size, free of sand or**

other impurities and without parasitic odours or infestation.

- **Consumers are sensitive to the colour, the texture, the aroma and the taste of the product after final cooking.**

These quality criteria, reflected in the price, are always present even if the current quality standards are not always respected.

8.1 Texture

8.1.1 Maize

Varieties with a floury texture are easier to mill than varieties with a vitreous texture which give more semolina and grits. To classify varieties according to their degree of vitreosity (from 1 to 5), the transversal cut surface of the endosperm is visually examined. A vitreous (or "glassy") grain will be Class 1, while a farinaceous (or "toothy") grain will be Class 5.

There is also a simple grinding test for grain which determines an index of hardness based on the size of ground particles. The lower the index the more difficult the grain is to grind. It has thus been possible to identify the yield of broken maize among varieties grown in Senegal.

In Togo, varieties of soft maize are more appreciated since they give a fine flour with minimum grinding. Improved varieties such as NH1F, Mexico 8049 or TZSR having similar processing qualities have been well accepted. On the other hand, a variety like La Posta, needing 2 or 3 passes though the mill are more costly to process and therefore attract less interest.

8.1.2 Sorghum

Contrary to maize, sorghum is usually hulled before grinding into flour. The yield from hulled Bin is higher for sorghum types with a hard endosperm compared to those types having a farinaceous endosperm (same classification principle as for maize).

8.2 Other characteristics of grain

8.2.1 Shape and size of grain

Sorghum varieties with round grain and/or large grain have a higher hulling yield. To obtain maximum yield, the grain should be divided into three groups - small, medium and large for separate hulling. If this is not done, small grain should be screened out before hulling. This is technically possible in the industrial installations which exist in Africa (Sudan, Senegal, Tanzania) but is rarely utilized.

8.2.2 Thickness of the pericarp

Mechanical hulling by the dry process gives better results from sorghum with a thin pericarp. On the other hand, manual pounding is easier with sorghum varieties with a thick pericarp.

8.2.3 Presence of tannins

The presence of tannins in certain varieties of sorghum is generally linked to the presence of a farinaceous endosperm and gives lower yields on hulling. Mechanical processing should be adapted to give a lighter abrasion of the pericarp.

8.3 Cleanliness of grain

This criterion of quality has a direct influence on the acceptability of the finished product. Before processing, the grain (maize, millet or sorghum) should be free of foreign matter (small stones, sand, soil, straw, string, metallic debris). Screening, winnowing, and, finally, washing are obligatory. The operators who sell the grain know this and always do it before pounding the grain or taking it to the local mill.

When selling grain to travelling traders, cereal banks or State authorities, the farmer does not worry about cleaning the grain after threshing or shelling because payment

does not depend on quality (cleanliness or homogeneity). Thus there is often 5% to 10% of impurities in the batch. The cost of cleaning (loss of weight and supplementary expenses) falls on the industrial buyer-operator and on the artisanal processors and users. When the industrial operator works with imported grain (maize or wheat) only a less costly complementary cleaning operation is needed. To decrease or increase the price according to the degree of cleanliness of the product would undoubtedly improve the respect given to cleanliness in commercial transactions.

8.4 The cooking quality of milled products

Traditionally in African couontries where maize, millet and sorghum are consumed, the flour has to have precise characteristics adapted to each dish. In Benin there are about forty different foods prepared from maize (Nago, 1989). The culinary quality depends on the skill and experience of the cook, and on the quality of the raw materials used. There are several predominant criteria of quality, mentioned below.

8.4.1 The colour

The colour of the milled product will be the same in the cooked product. In general, light coloured products (white, yellow, pink) are preferred to dark colours (grey or red).

8.4.2 The granularity

This depends on the size of the grains in the final product: coarseness of semolina or fineness of flour; hulled grain more or less broken. The measure of granularity is easily achieved with the aid of standard mesh sieves available on the market.

The flour obtained from pounding in a traditional mortar has 22% to 46% moisture content. Its rapid fermentation, appreciated in culinary preparations, does not permit conservation beyond one or two days. In town, where the grain is milled dry or is processed in mini-mills, it is difficult to produce a flour or semolina correctly de-germed and ground for good conservation for 1 to 2 months which gives, after storage, the same cooking quality as a fresh product.

At present there is no small scale equipment capable of de-germing grain effectively. Hulling by external abrasion does not eliminate the portion of germ embedded in the endosperm. To remove this, it is first necessary to break the grain as is done in industrial installations. But since the final de-germed product achieves a yield of no more than 70%, it is more expensive.

There is currently a need to market a partially processed product having an intermediate granularity which can be used in certain dishes or re-ground by the cook for other uses (as in the case of "Sanka!" or crushed millet and "soungouf" or milled flour in Senegal).

8.4.3 The texture

The texture of a product is linked to its capacity to absorb water and its behaviour on cooking. The measure of the texture of the "to" or "porridge" made from millet, maize or sorghum has been the object of laboratory study at the IER in Mali and CIRAD in France. The same procedure is in progress to characterize other dough-type products such as "ogi" and "akassa" in Benin or granulated or rolled products such as couscous,

"arrow" and "aklui" in other parts of West Africa. When planning to industrialize the manufacture of ground products for used in traditional dishes, it is possible to determine the influence of the varieties and the milling technique employed on the quality of the final cooked product.

Conclusions

A review of the difficulties failures encountered in various technology extension projects in Africa has enabled us to draw up the following list of bottlenecks to be avoided:

- **A technology which is not adapted to the production or processing requirements of the end-users: either because maintenance is too difficult (due to problems in obtaining spare parts) or the technique is not appropriate for the local varieties (the case with certain de-hullers);**
- **A technology which does not respond to the socio-cultural characteristics of the**

end user (taste and preferences);
- **A technology which is either too sophisticated or over-sized, with high operational and maintenance costs;**
- **Organizational and managerial problem resulting in a lack of participation of those people involved, and an insufficient managerial capacity;**
- **A lack of enterprise to search for financial resources and a limited knowledge of marketing for such activities.**

After having reviewed a large number of post-harvest technologies, we have made an assessment of the experience acquired in sub-Saharan Africa. On one side, it seems that traditional technologies carried out by farmers over the years have proven useful. They are still are still predominantly in use today because they are well anchored in the culture of the various ethnic groups. Nevertheless, the socio-economic evolution and the ecological changes have considerably altered the production and marketing conditions for staple foods (grain and tubers). The post-harvest system must therefore be adapted to the new context which is continuously evolving.

The first technological adaptation is already taking place more or less successfully. The constant improvements in existing technologies respond more positively to new marketing requirements following the course of technical progress. In fact, technical solutions do exist and can be disseminated through shared experiences such as is

given in this report, by developing field research and training farmers to adapt to the new technologies.

The second adaptation is another matter. It means modifying people's mentality with regard to socio-economic changes in order that they can adapt to the market, and improve the quality of production, taking into account environmental constraints. This new type of "human" experience is, undoubtedly, the most difficult to surmount as it comprises technical, collective and individual factors. This document is reporting the African experience in postharvest technology. Let us hope it will allow each person involved in development to draw some valuable information to help him achieve his own experience.

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