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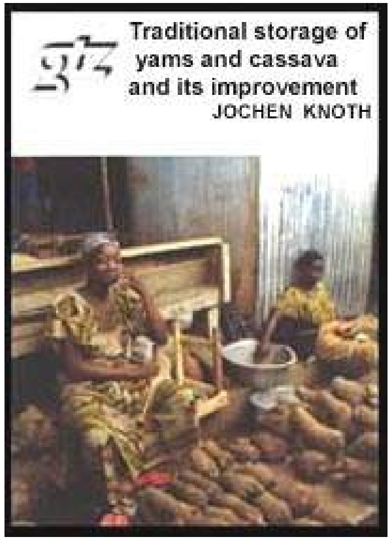

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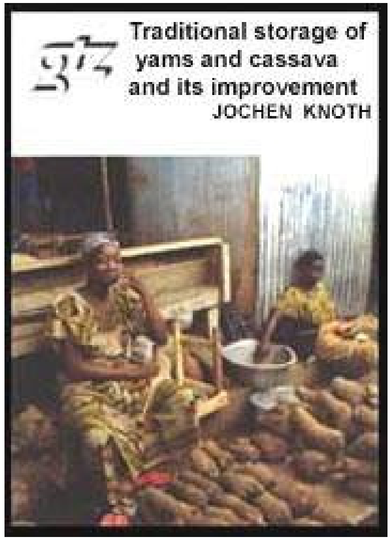

Traditional Storage of Yams and Cassave and its Improvement (GTZ)

JOCHEN KNOTH
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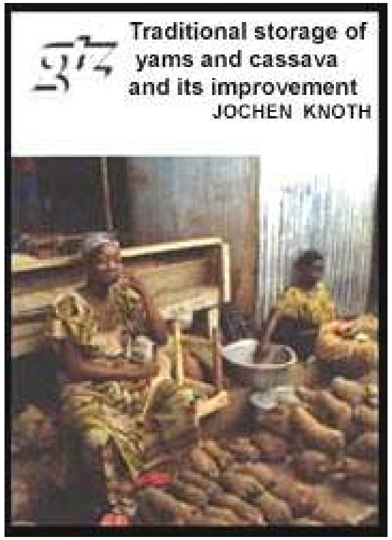

Preface

According to estimations by the FAO almost 100 million tons of roots and tubers are harvested annually in Africa. Of these, 77 million tons alone are cassava and yams, the most important staple foods in this group, which constitute almost 16% of the food consumed by the 575 million inhabitants of Africa.

In the past, roots and tubers were mainly subsistence crops With the increased tendency to urbanisation and thus more and more dependence of the African people on low-price foods, a gradual move away from subsistence crops towards cash crops has occurred To accommodate this, wide groups of the rural population have been able to enter into commercial agriculture and now not only cultivate crops to secure food for themselves

After harvesting, roots and tubers are perishable products and are subject to high losses during transport, storage and selling if the potential for food security is to

be exploited to a more extensive degree, it will become indispensable to process these into products which can be stored without suffering great losses in practically applying measures towards this, the African women are extremely important

This brochure appearing in German, French and English presents an outline of the socio-cultural and economic aspects of cassava and yam production and summarises the most important findings currently available on processing and storage techniques.

This publication is to constitute a basis for more extensive advisory services and further investigations into the practical application of such methods. It is anticipated that restricting losses will lead to a greater area being cultivated and to a reduction in the work burden on women in Africa

J. Christenn

Bundesministerium fr wirtschaftliche
Zusammenarbeit
Referat 223

A. Bell
Deutsche Gesellschaft fr technische
Zusammenarbeit (GTZ) GmbH
OE 423

Abbreviations

ARCT	African Regional Centre for Technology
CIAT	Centro Internacional de Agricultura Tropical
DSE	Deutsche Stiftung fr Internationale Entwicklung
FAO	Food and Agriculture Organization
GFA	Gesellschafl fr Agrarprojekte m.b.H.
GTZ	Deutsche Gesellschafl fur Technische Zusammenarbeit
IITA	International Institute of Tropical Agriculture
INPT	Institut National de Plantes Tubercule
NRI	Natural Resource Institute
TPI	Tropical Products Institute

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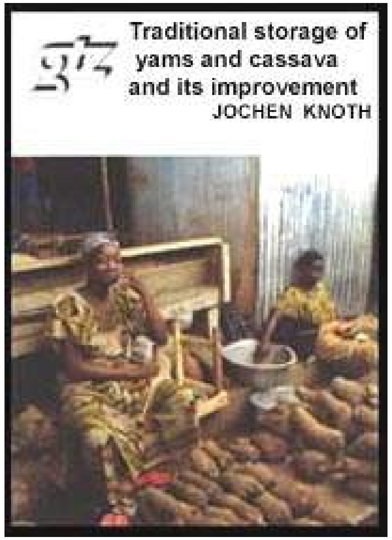

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1 Introduction

In addition to cereals, roots and tubers are the second most important group of food crops. This particularly applies to the part of Africa south of the Sahara where, of the total foodstuffs produced, roots and tubers make up 31 % and cereals 53% (PAULINO AND YEUNG, 1981). in western African countries (Ivory Coast, Ghana, Nigeria...) more than 50% of the supply of calories is derived from the cultivation of roots and tubers (OKIGBO, 1987).

The most significant root and tuber crops produced in Africa are cassava and yams with annual quantities of 51 and 24.4 million tons respectively which correspond to around 40% and 96% of world production.

Table 1: Cultivation area (in 1,000 hectares - 1984) for various tropical roots and tubers according to regions

Region	Cassava	Yams	Sweet Potatoes	Cocoyams
Africa (total)	7 480	2 395	841	93
West Africa	2 500	1 550	139	50
Asia	4170	16	6 390	18
North Central America	170	49	217	-

South Africa	2 310	40	162	-
Oceania	20	18	116	5
World	14 150	2 518	7 738	115

Source: FAO, 1985 (modified)

In Africa, roots and tubers are cultivated almost exclusively by small farmholder to secure their own subsistence Only about 20% of produce is marketed (FAO, 1986) The quota sold varies from region to region and is far lower in rural areas than in the catchment areas of conurbations. The reason is to be found at least partly in the high transport costs in comparison to cereals which makes production near to consumers more favourable (LYNAM, 1991)

Table 2: Production (in million tons - 1984) of various tropical roots and tubers according to regions

Region	Cassava	Yams	Sweet Potatoes	Cocoyams
Africa (total)	51,0	24,4	5,1	3,4
West Africa	17,8	18,5	0,8	2,6
Asia	50,0	0,2	108,6	2,0
North/Central America	0,9	0,3	1,5	
South America	26,9	0,3	1,4	
Oceania	0,2	0,3	0,6	0,3
World	129,0	25,s	117,3	5,7

Source: FAO, 1985 (modified)

A steady decline in the production of yams amounting to an annual average of over 1% has boon observed for Africa over a decade. During the same period, the production of cassava increased annually by 1.7% but remained well behind the population growth rate of Africa (OKlGBO, 1987)

The production of roots and tubers especially in Africa is in an area of conflict involving various forces. Roots and tubers indubitably have considerable production potential which can lead to an improvement in nutrition on the African continent. The output of roots and tubers per unit of area is superior to cereals grown under the same agroclimatic conditions. Particularly cassava provides acceptable yields even on very poor and acidic soils which are typical for the tropical areas of Africa. Roots and tubers survive longer dry periods and are far less susceptible to mass pests (locusts and bird pests etc.) than cereals. This has led to cassava particularly becoming widespread on small farms in Africa since the beginning of the 20th century (LYNAM, 1991).

The high water content in roots and tubers is on the one hand the reason for the low price per unit and, secondly, makes the fresh roots and tubers unsuitable for transport ((HAHN, 1989). The high water content makes storage difficult which frequently involves high losses. These two factors constitute an obstacle for further increases in the production of roots and tubers.

Table 3: Average yields (tons per hectare - 1984) for various tropical roots and tubers according to regions

Crop	Africa	Asia	South America	Oceania
Cassava	6,82	11,99	11,62	10,69
Yams	10,20	10,21	8,42	13,7
Sweet Potatoes	6,11	16,99	8,86	4,83
Cocoyams	3,67	11,32	11,11	6,89

Source: FAO, 1985 (modified)

The labour productivity of roots and tubers is mostly low, particularly when this includes the necessary processing of products to preserve them. In rural regions where there is a high migration rate, the low labour productivity seriously restricts production

The production of roots and tubers is often impeded by national agricultural policy in many areas, the consumption of imported cereals is subsidised and has a negative effect on the demand for traditional food crops (VEELBEHR, 1991). The substitution in cities of roots and tubers by other staple foods containing starch is not price-induced but is a result of labour management factors. The opportunity costs for women's work in urban areas are far higher than the country. This encourages the demand for foods which require only a low rate of work input for their preparation (LYNAM, 1991)

Although national and international agricultural research institutes have also concerned themselves in the meantime with roots and tubers, the expenditure involved in research is very low in comparison to the significance these crops have for human nourishment (LEIHNER, 1991). Research so far has mainly been

centred on cassava which is the only tropical root and tuber which plays some role in world trade. Research focussed mainly on aspects concerning cultivation, phytopathology and increases in yield.

Aspects of storage and post-harvest protection have rarely boon dealt with in the past This particularly applies to storage for small farmers, although this group of producers is the one which cultivates and stores the most roots and tubers especially in Africa.

Table 4: investments by developing countries research into various food plants containing starch (in US dollars, 1975)

Crop	**Production value (US$ million)**	**Investment in research Total (US$ million)**	**Share in production (%)**
Sorghum	1500	12	0,77
Maize	3 000 - 4 000	29	0.75
Wheat	5 000 - 6 000	35	0,65
Sugarcane	5000 - 6000	12	0,50
Rice	plus de 13 000	34	0,26
Sweet Potatoes	3 000 - 4 000	3	009
Cassava	5 000 - 6 000	4	0,07

Source: ace. to COCK, 1985 (data refers to 1975)

According to LANCASTER AND COURSEY (1984) it must be assumed that die losses of roots and tubers in post-harvest handling amount to around 30% of production volume Even a slight decrease in storage losses could lead to:

- the supply of foodstuffs being increased and seasonal fluctuations being evened out,
- natural resources being conserved, since neither more area nor additional production input towards increasing the crop are involved,
- an improvement in the country's own supply of foodstuffs and thus a contribution to balancing the movement of foreign exchange,
- living conditions in the country being improved by better supplies of staple foods and a simultaneous increase in the proportion available for sale, and thus to restricting rural-urban drift

Knowledge of traditional storage systems and likewise, their socio-economic and cultural background, only exists to a limited extent. In view of this, and of the significance of an improved storage system from a microeconomic as well as macroeconomic aspect, it is the purpose of this investigation to:

- systematise the knowledge available on traditional storage systems for roots and tubers,
- make gaps in knowledge visible, and
- to define approaches for possible improvement measures.

This investigation cannot deal with all tropical roots and tubers; it must be restricted to cassava and yams which are the two most important representatives of this group of food crops in Africa

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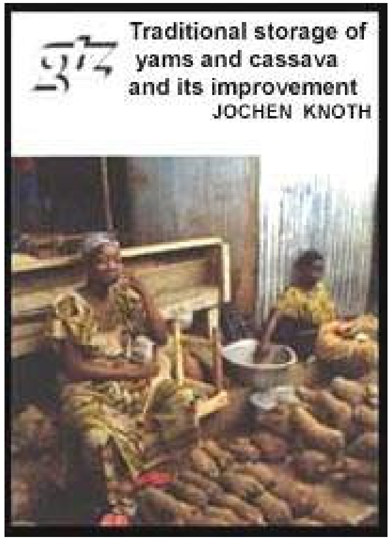

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2 Socio-cultural aspects involved in the production of roots and tubers

Seen from the perspective of the history of mankind, the societies whose nutrition is based on the cultivation of roots and tubers are very old cultures The settlement areas for these societies originally comprised the whole of the tropical equatorial region.

During the course of history, almost all "root and tuber societies" have either been infiltrated by cereal cultivating societies or destroyed by their hegemonic strivings. More or less intact "root and tuber societies" have only been able to survive and retain their cultural heritage until today m West Africa (Yam Belt) and on some islands of Oceania (COURSEY, 1981).

This, however, does not mean that all other former "root and tuber societies" which have been modified by external influences, have lost their specific heritage. On the contrary in these societies, the customs and traditions showing the high cultural status of roots and tubers have survived.

Thus the vegetation cycle (planting, harvesting and storing) is frequently embedded in a series of rituals serving to protect the roots and tubers The harvest of roots and tubers is tabooed until certain rituals supported by religious sanctions have been carried out.

In these societies, the individual plant often has a greater significance than the crop population. For yams for example, ridge beds and staking systems are set up for each individual plant it is the aim to maximise the yield for each plant (largest possible tubers) and not to maximise the area output. This concentration on the individual plant is also illustrated harvest technology: with the greatest care, only a definite number of tubers is harvested from each plant allowing it to continue to grow.

Post-harvest technology is also in line with the desire for harmony in these societies. The purpose of this is more to avoid longer periods of storage than to develop improved storage systems (LANCASTER and COURSEY, 1984). This may

be one reason why traditional storage systems have a very simple concept and often show no signs of endogenous development. The traditional store for yams (yam barn) in West Africa does not only serve to preserve the tubers. It also has a symbolic character and is a sign of the economic prosperity and of the social influence of its owner

The overall field of post-harvest activities in these societies is often seen as an extension of household activities. It is therefore not surprising that the post-harvest tasks are the responsibility of the woman (LANCASTER and COURSEY, 1984) Gender-specific division of labour however, shows some differences depending on the variety of crop. The woman is thus involved in cultivating and storing cocoyams and cassava or even in charge of this. In contrast, the cultivation and storage of yams is exclusively a matter for men

Gender-specific division of labour is not exclusively based on traditional behaviour patterns Changes in socio economic conditions, e.g. temporary migration for reasons of employment, also affect labour division and cause changes in role allocation between man and woman.

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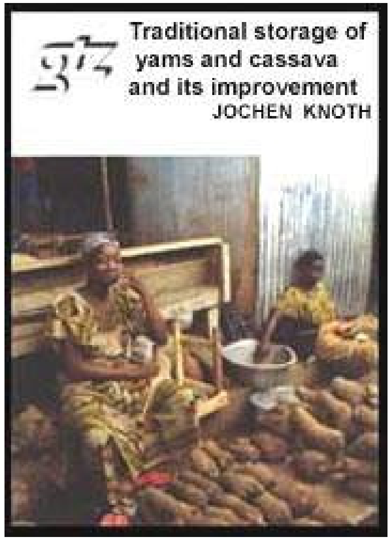

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3 Basic comments on the storage properties of roots and tubers

In contrast to cereals which have good natural properties making them suitable for storage, tropical roots and tubers are, without exception, perishable crops The factors determining the difference between these two product groups and their storage properties can be seen in Table 5

From the varying determinants affecting the storage behaviour of these two groups of products it is evident that storage methods which have proven suitable for durable food crops cannot simply be applied to perishable crops. In addition, the roots and tubers are not a homogenous group where their storage properties are concerned but show varying differences specific to each product. It therefore becomes necessary to develop specific storage methods for each root and tuber, which is illustrated by the great variety of traditional storage systems.

It is for this reason that this investigation will proceed to treat both crops, yams

and cassava, in separate sections

Table 5: Comparison of cereal storage properties with those of roots and tubers

Durable food crops	**Perishable food crops**
pronounced seasonal harvest, long-term storage necessary	continual or semi-continual harvesting possible. Long-term storage this often avoidable
processing (apart from threshing) to prepare the produce rarely necessary	processing to dried products often an alternative to storing fresh produce
low moisture content of crops, mostly between 10 - 15% or less	high moisture content of crops, mostly between 50 - 80%
small units mostly weighing less than 1 gramme	large units, mostly weighing between 5 g and 5 kg or more
slow respiratory activity of stored crops and thus low development of heat	high to very high respiratory activity of stored crops, consequently great degree of heat development particularly under tropical conditions
hard condition of tissue, good protection from injury	soft condition of tissue, easily injured
stable, good natural preservation, storage possible over several years	perishable, natural preservation of up to several months (great variations in species and varieties)
storage losses mostly	losses partially endogenous (respiration, transpiration,

exogenous (mould, insects, rodents)	germination), partially exogenous (rot, insects)

Source: FAO, 1984 (modified)

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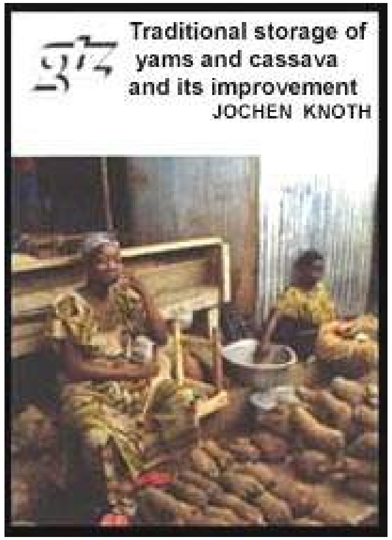

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4 Yams

Yams are widespread in the humid tropics throughout the world and in a wide variety of species. Of particular significance are the white Guinea yam (Dioscorea rotundata Poir), the water yam Dioscorea alata L.), the yellow yam Dioscorea cayenensis Lam.) and the Chinese yam Dioscorea esculenta (Lour.) Burk.)

The white yam originates in West Africa, however, without a wild variety being known of it is the most important variety of yam cultivated for human nutrition not only in this region, but throughout the world.

Most widespread, but not of the greatest economic status, is the water yam. This variety is native to South East Asia and probably originates in Burma, today's Myanmar. The water yam, with the white yam, is the most important variety of yam cultivated in West Africa today.

The appearance of the yellow yam is very similar to that of the white yam Many authors also speak of a subspecies here (ONWUEME, 1978). Apart from some morphological differences, the yellow yam has a longer period of vegetation and shorter dormancy than the white yam. The yellow yam is native to West Africa where wild varieties also exist. Apart from the region of its origin, the yellow yam is only found with economic significance in the West Indies.

The Chinese yam comes from Indo-China. Nowadays it is most widespread in South East Asia, in the South Pacific and in the West Indies The Chinese yam has

only recently been introduced to Africa and has only played a subordinate role here so far

The bitter yam (Dioscorea dumetorum (Kunth) Pax) is marked by the bitter flavour of its tubers. Some sorts are highly poisonous. The cultivation of the bitter yam is mainly limited to the West African region where wild varieties cam be encountered

There are many other varieties of yam, some of these are only of regional significance and do not occur in West Africa For this reason, a more detailed description of these can be dispensed with here.

4.1 The environmental requirements of yams

The yam is a plant of tropical climates and does not tolerate. Temperatures below 20°C impede the growth of the plant which needs temperatures between 25 and 30°C to develop normally.

Most varieties of yam have a growing phase of 7 - 9 months up to maturity. The yam requires an annual precipitation of over 1,500 mm distributed evenly over the vegetation period to take full advantage of its production potential. For this reason, a long rainy season during the growth period has a positive effect on the yield of yams Off the other hand, the plant is able to survive longer dry periods which, however, reduce the yield considerably

The yam makes high demands on soil fertility. Soils with a high humic content correspond best to the requirements of the yam. On soils which are low in nutrients and which are predominant in the humid tropics, the yam is often the

first member in crop rotation so that its high demand on nutrients can be fulfilled In addition to a high concentration of nutrients, the soils should have good water-bearing properties as yams are not able to tolerate stagnant water. They also need deep soil which is free of stones. Shallow or soils impede the formation of the tubers and or result in deformity.

Although not completely analysed, there are many indications of light intensity affecting growth - in particular of the tuber. Thus staking for the tendrils promotes the yield Semi-shade, e.g. in a greenhouse or under trees, leads to a noticeable loss in yield (ONWUEME, 1978).

4.2 The yam tuber

Economically the most important part of the yam is its tuber This can vary greatly in shape and size and makes manual harvesting very difficult and has so far prevented any kind of mechanisation in harvesting. Cultivated forms of yam mostly produce cylindrical tubers which cam be very heterogeneous in size and weight.

The outer part of the tuber forms several layers of cork. These layers constitute effective protection from lesions, water loss and against the penetration of pathogens in the soil as well as in storage after the harvest The inner part of the tuber is formed by a tissue which is interwoven with vascular channels Carbohydrates, mainly in the form of starches, are stored in this tissue. Apart from the most important constituents of the tuber, water and carbohydrates, this also contains small quantities of proteins, fats and vitamins. As can be seen from Table 6, the tubers of various varieties of yam differ in the relative composition of their constituents.

Table 6: The composition of various species of yam tubers

Variety	Moisture	Carbohydrates	Fats	Crude protein
D. alata	65-73	22-29	0,1-0,3	1,1-2,8
D. rotundata	58 - 80	15 - 23	0,1 - 0,2	1,1 - 2,0
D. esculenta	67-81	17-25	0,1 -0,3	1,3- 1,9
D. bulbifera	63-67	27-33	0,1	1,1-1,5

NB. The figures have been rounded. The results for D. rotundata correspond to those for D. cayenensis which was not included in the table
Source: Coursey, 1967 (modified)

The yam tuber is primarily for vegetative propagation if complete tubers are used for propagation, germs will form in the region of the head. Also segments of the tuber can germinate as long as these include a piece of the outer surface of the tuber. The ability of the tuber to form germs at any point on its surface is made use of by the "Miniset Propagation Method" (INPT, 1988). Using this method, the plants required per hectare can be reduced from approximately two tons to approx. 400 kg

4.3 Farm-economic aspects of yam production

The yam is a demanding plant in every respect. Its demands on the soil fertility mean that it is mostly the first member in crop rotation.

The preparation of the fields, ridging, vegetative propagation mulching, weed

control and harvesting mean a great input of work. About 500 working days have to be calculated per hectare with a harvest yield of 10 tons of tubers (COURSEY, 1966) There is also little indication of relief through mechanization, even for parts of activities (ONWUEME, 1978).

According to the variety and sort of yam, the production potential to 20 - 50 tons per hectare. The average yield m Africa however. only amounts to around 10 tans per hectare (FAO, 1985). Of these, 2 tons per hectare have to be reserved for traditional propagation, leaving only 8 tons for consumption.

The output per unit area for the yam is very high However, it must be considered that yams can only be grown in primary locations. Labour productivity is low. This may be a reason why yam production is stagnating m many places or is even declining. In Togo between 1911 and 1986 yam production fell from 807,000 tons to 409,000 (INPT, 1988). This is mainly due to a shortage of manpower m rural regions. The stagnating production must also partly be seen as a result of an increasing concentration of the population. This effects a higher and higher production index for arable land and the cultivation of boundary locations Both restrict the cultivation of yams; but promote the cultivation of cassava (cf. Chapter 5.3) which is gradually replacing the yam in many places.

4.4 Yam harvesting

There are two processes of harvesting yams:

- **single harvest**
- **double harvest**

The single harvest involves harvesting all the tubers of a plant in one working procedure. The time for harvesting is not a critical date since one month prior to wilting point (sign of physiological maturity of the tuber) the growth of the tuber is extensively completed. Harvesting should however be finished within 1 - 2 months of the wilting point, or otherwise losses due to tuber rot must be expected (ONWUEME, 1 978).

The double harvest is divided into a first and a second harvest Depending on the sort of yam, the first harvest takes place about 4 - 5 months after emergence of the plants. The tubers are carefully uncovered and separated from the plant without damaging it. After the harvest, the bed which has been dug open is re-prepared The plants react to this interference with increased production of tuber tissue so that a second harvest can take place after the wilting point.

The double harvest the properties of the tuber The tubers from the second harvest have pronounced "planting features.' and are less suitable for eating. Thus the high work input in the process of double harvesting is mainly for the purpose of producing plants for vegetative propagation.

The tubers from the first harvest are available early. They are highly estimated and attain correspondingly high prices on the markets.

The double harvest is a process with a very high input of labour. Mechanisation is very difficult which means work relief through the use of technical progress is hardly possible (ONWUEME, 1978).

4.5 Causes of storage losses for yams

Losses which can occur during the storage of fresh yams have very varying causes Some of the losses are endogenous, i.e. physiological These include transpiration, respiration and germination Other losses are caused by exogenous factors like insect pests, nematodes, rodents, rot bacteria and fungi on the stored produce

4.5.1 Dormancy

The possibility to store fresh yam tubers is decisively influenced by their dormancy Dormancy occurs shortly after physiological maturity of the tubers (wilting point). During dormancy, the metabolic functions of the tubers are reduced to a minimum. Dormancy evidently serves to facilitate the tuber, as an organ of vegetative propagation, to overcome an unfavourable climatic period. Consequently, varieties of yam native to regions with marked arid seasons have a longer period of dormancy that those native to regions with shorter dry seasons. The duration of natural dormancy fluctuates according to the variety of yam between 4 and 18 week (cf. Table 7).

Table 7: Comparison of dormancy duration for different varieties of yams in selected locations

Varieties	**Location**	**Dormancy (in weeks)**
D. alata	Caribbean	14 -16
	West Africa	14-18
D rotundata	West Africa	12 -14
D. cayenensis	West Africa	4 -8
D esculenta	West Africa	12 -18

	Caribbean	4 - 8

Source: PASSAM, 1982 (data from various sources compiled by the author)

The varying length of natural dormancy determines that the different varieties of yam have more or less good natural storage properties. The duration of dormancy however does not only depend on the plant but is also influenced by physical factors. A fall in temperature, even if this is only a few degrees Centigrade, prolongs dormancy. Vice versa, a rise in temperature reduces dormancy (PASSAM, 1982). Relative humidity also has a similar effect. High humidity e.g. at the beginning of the rainy season, promotes germination Low humidity on the other hand, prolongs dormancy (WICKHAM, 1984)

4.5.2 Transpiration

Depending on the variety, yams have a water content of 60 - 80% During storage, the water content of the fresh tubers reduces continually. Water loss vanes depending on the phase of storage During the first weeks after harvesting, a reduction in the water content of the tuber is hardly noticeable in some cases, water content will even rise slightly during this phase (COURSEY, 1961)

During a storage period of five months, the weight of the tuber falls by up to 20% due to transpiration (COURSEY and WALKER, 1960) Data concerning the loss of weight due to transpiration show some difference. The reason for this is that the intensity of transpiration is considerably influenced by the predominant climatic conditions (temperature and relative humidity).

Loss of weight due to transpiration has no influence on the nutritional value of the tubers can even rise in relation due to transpiration. Despite this, a great loss in weight from transpiration is not desired Due to this, the tubers lose their viability (germination), shrink, become unattractive and undergo a change in flavour which is not wanted (ONWUEME, 1978). As yams are mainly sold according to fresh weight and appearance, it is in the interest of the farmer to preserve the water content of the fresh tuber as much as possible (ONWUEME, 1978).

4.5.3 Respiration

The yam tuber is a living organ. This is why metabolic functions continue during dormancy to preserve its viability. The energy essential for this is taken by the tuber from its store of carbohydrates. Carbohydrates are burned to gain energy during which process CO_2 and H_2O are emitted to the environment as gases.

In contrast to transpiration which only causes water loss in the tuber, respiration involves the use of stored energy. This consequently is lost for human nourishment. During dormancy, one kilogram of tubers stored at 25°C loses the equivalent of 3 ml CO_2 per hour (PASSAM and NOON, 1977)

Table 8: Proportion of respiration in the total loss of weight during storage using the example of 1). rotundata

Age of tuber weight loss in %	**weight loss per day in %**		**Proportion of respiration in**	
	25°C	35°C	25°C	35°C
After harvesting	0,22	0,36	27	30

During dormancy	0,15	0,28	7	10
During germination	0,21	0,34	35	20

Source: Passam, 1982 (modified)

The weight losses occurring during storage due to respiration and in general are shown in the table. It becomes clear here that the weight losses depend on the storage phase and the storage temperature. It is also clear that respiratory losses are not as strongly influence by the as the transpiratory losses.

4.5.4 Germination

Germination marks the end of dormancy for the yam tuber Germination does not occur at the same time for all tubers of one variety which are stored together. Germination is more a dynamic process and takes place gradually.

Environmental effects, in particular relative humidity and temperature, affect germination It was observed by PASSAM (1977) that tubers of Dioscorea rotundata already germinated after 20 days at a humidity of 100% and a temperature of 25°C. At the same temperature and a relative humidity of 60 -70%, germination began after 40 days, and at 17-C and a humidity of 100% after 30 - 40 days (ibid).

Whether in addition to humidity and temperature, of her factors e.g. direct sunlight, affect the beginning of germination, has not yet been clarified. Whether

the plants own growth hommones affect germination is also not clear.

Energy required to form the germ is taken from the carbohydrate reserves. During the process of germination, the tuber quickly loses nutrients, dries out and rot pathogens penetrate it so that further storage becomes impossible (PASSAM and NOON, 1977).

4.5.5 Rot due to mould and bacteriosis

Tuber rot caused by various pathogens is one of the most significant causes of loss during the storage of fresh yam tubers.

The fungi causing rot are normally lesion pathogens. They can only actively penetrate the tuber through lesions, cuts, holes bored by nematodes or where rodents have bitten the tubers (COURSEY, 1967). Frequently only one variety of fungus penetrates the tuber initially and is then followed by others

There are various types of rot on the yam tuber. Depending on the consistency these are distinguished by "dry", "watery" and "soft" rot (CENTRE FOR OVERSEAS PEST RESEARCH, 1978) Rot can infest only parts or the complete tuber "Dry" rot can often not be observed externally Rot effects changes in consistency and flavour frequently the tubers no longer suitable for consumption or causing a considerable loss in market value. Bacteria can also cause rot However, these are not as aggressive as mould fungi

There are numerous species of mould fungi which infest yam tubers but often these are only of regional importance. The following are among the most significant species:

- **Botryodiplodia theobromae,**
- **Penicillium.spp,**
- **Aspergillus spp,**
- **Fusarium bulbigenum (COURSEY, 1982).**

4.5.6 Nematodes

Nematodes occur on yams as root and tuber parasites The nematodes mostly infest the plant during the vegetation period and remain in the tubers after the harvest. They damage not only the tubers themselves but also create entries for other pests, in particular for mould fungi For this reason infestation by nematodes is often accompanied by tuber rot which mostly causes greater economic damage than infestation only by nematodes.

The yam worm (Scutellonema bradys) is one of the most important nematode parasites of the yam tuber. The yam worm particularly damages the periderm and subperiderm, cell layers which are directly under the cork shell. The beginning of infection can be detected by narrow, yellow wounds which are directly under the shell. In the course of time these wounds become brown. On the exterior, deep cracks indicate infection The yam worm can cause symptoms of dry rot if other pathogens are missing (CENTRE FOR OVERSEAS PEST RESEARCH, 1978). As the yam worm destroys the meristem, the tuber often loses its germination capacity as a result of infection (ibid.)

The root-knot nematode (Meloidogyne spp.) is a widespread pest in the tropics. Several varieties of this pest also infest the roots and tubers of yams. The root-knot nematode lives freely in the soil and can penetrate softer parts of the tuber.

The larvae grow quickly in the adult phase only the females are parasites These lay their eggs in the tuber as well as in the earth surrounding it. After harvesting, the larvae and eggs continue to live in the tuber The root-knot nematode causes nodulated and often wrinkled and shrunk yam tubers (CENTRE FOR OVERSEAS PEST RESEARCH, 1978).

The root-lesion worm (Pratylenchus spp.) infests the tubers as a larva or as an adult worm It causes dark-brown dry rot which penetrates the tuber irregularly In some cases, the shell of the tuber is tom open by the infection leaving the way free for secondary infections (CENTRE FOR OVERSEAS PEST RESEARCH, 1978).

In addition to the nematodes mentioned above there are a number of others which are parasites to the yam tuber. However, these are only of secondary importance.

4.5.7 Insects

There are varying statements in literature about damage caused by insects to stored tubers (incl. COURSEY, 1967; ONWUEME, 1978). According to investigations carried out by SAUPHANOR and RATNADASS(1985), it can be assumed that the pressure of pests will become regionally more important due to pests which are introduced accidently.

Insects damage the yam tubers in two different ways: on the one hand they cause losses of substance due to injury and in addition, can reduce germination capacity. On the other hand they damage the epidermis allowing rot fungi in particular to penetrate the tuber and cause secondary damage.

The yam beetle (Heteroligus spp.) according to details stated by ONWUEME

(1978), is the insect which causes the most damage to yams in West Africa it attacks the tuber during the growth phase which then only rarely dies. The epidermis is destroyed during eating leaving the way open for secondary infections leading to mould, which can cause high storage losses

Other extensively widespread pests which infest the yam tuber during storage are mealy bugs and yam mealy bugs (Aspidiella hartii and Planococcus dioscorea). These from whitish colonies which can cover the whole tuber The insects suck the juice out of the tuber leading to a certain loss in weight. However, what is more significant is that the tubers which are infested are not suitable for sale and the mealy bugs have a negative effect on germination capacity (SAUPHANOR and RATNADASS, 1985).

The most important insect pests of stored yam tubers are a pyralid moth (Euzopherodes vapidella) and a moth (Tineidae sp). The pyralid moth normally infests the tubers shortly after the harvest it lays its eggs in existing wounds but can also penetrate the epidermis for this purpose The pyralid moth prefers D. alata varieties, which in to other varieties have a high water content Infestation causes a loss of substance in the tuber.

The tinned moth prefers D. cayenensis varieties as these contain comparatively more starch. The tineid often occurs as a secondary pest after the pyralid moth when the plant has already lost moisture due to the pyralid moth. The moth's larvae can eat out the infested tuber within a month leaving only the corked epidermis Both species seem to be gaining in importance in the region of West Africa although in the past the pyralid moth was only widespread in Nigeria. Since the seventies it has also appeared in the ivory Coast (SAUPHANOR and

RATNADASS, 1985).

Other groups of pests are termites which cam penetrate storage. These voracious insects penetrate the epidermis and set up corridors in the tuber. Termites can eat out whole yam tubers within only a few weeks

Losses in storage due to insects are difficult to quantify. Investigations carried out in the ivory Coast came to the conclusion that 25% of losses after four months of storage were caused by insects Secondary infections were not taken into account in the calculations (SAUPHANOR and RATNADASS, 1985).

4.5.8 Mammals

Among mammals, rodents are the most important pests for stored yam tubers. In the region of West Africa most damage is caused particularly by the giant rat (Cricetomys) and the common rat. (Rattus) (ONWUEME, 1978). Stored yam tubers are also popular with monkeys and warthogs as well as with domestic animals like goats and sheep.

Mammals primarily cause quantitative losses by gnawing. However, they frequently contaminate the stored produce with their excrements. By eating, mammals damage the epidermis of the yam tubers which promotes rot infection Tubers showing only slight damage from gnawing cam thus be completely destroyed by a secondary infection.

Mammals cam cause damage in all kinds of open storage facilities. Particularly at risk are stores where the tubers lie directly on the ground

4.6 Traditional storage systems for fresh yams

Climatic conditions m humid and semi-humid tropics promote continous methods of production. Despite this, the yam is a seasonal fruit and can only be harvested at certain times throughout the year. Even if several yam varieties are included in crop rotation, a continuous supply of fresh yams cannot be provided over the whole year. For this reason, they have to be stored so that bottlenecks in supply cum be avoided Storage is also necessary for the purpose of preserving plants for vegetative propagation

For appropriate storage, very varied systems of storage for yams have been developed m West Africa, the centre of yam cultivation. These systems are mostly marked by simple technical solutions and frequently have existed since time immemorial without having undergone any substantial changes..

The types of storage structures are influenced by various factors. These include climate, purpose of the yam tubers in storage and socio-cultural aspects of storage (symbols of prosperity, use for cult purposes). However, the storage structures are also influenced by the type of building materials available and the resources of the farms, in particular, the availability of labour and d capital (FAO, 1990)

The storage systems existing in West Africa have only been mentioned rudimentarily m literature so far. Many determinants and interactions concerning these systems have to be considered unknown (CHINSMAN and FIAGAN, 1987) All systems are in need of further analyses to define the features relevant to storage. In the following chapters a number of storage systems widespread in West Africa,

will be described. Due to the limited amount of literature on this subject the descriptions cannot be seen as complete

Statements on possible storage periods and storage losses are very varied (COURSEY, 1967; NKPENU and TOUGNON, 1991). Apart from this, a standardised method of defining storage loss does not yet exist. This means that the methods and approaches in analysing and defining the losses are not standardized Furthermore, it must be remembered that the farmers under some circumstances may judge the losses in a different way from us as their assessment is primarily oriented to quantity. In view of this uncertainties the small amount of data illustrating storage periods and losses is to be dispensed with here.

4.6.1 Leaving the yam tubers in the ridges after maturity

The yam tubers are ripe for harvesting when the foliage has died. Without having to fear any great loss in yield, the harvest cum then take place some time afterwards and the tubers can simply be left in the ridges. The duration of this type of storage depends on the particular variety of yam and cum extend over 1 to 4 months (COURSEY, 1983).

From an economic point of view, this method of storage is quite feasible since no costs are incurred in erecting a store. However, opportunity costs have to be allocated to this method as the field cannot be, or only partly, used otherwise due to the yam tubers remaining there. This method provides no protection from pests (insects, nematodes and rodents) or rot (COURSEY, 1967). Neither does this method allow a periodic check of the condition of the stored produce. During the dry season when the ground dries out and becomes as hard as rock, harvesting

without greater losses becomes almost impossible (NWANKITI and MAKURDI, 1989).

4.6.2 Storing the yam tubers in trench silos

The yam fields often have to be located a considerable distance away from the settlements As particularly during harvest time labours is only available to a limited extent, the farmers make silos in the fields or on the edges of the fields This saves on labour necessary for transportation during the harvest

A typical storage facility made in the fields is the trench silo To make this, a pit approximately corresponding to the expected volume of yams to be harvested is excavated The pit is lined with straw or similar material (NWANKITI and MAKURDI, 1989) The tubers are then stored on the layer of straw either horizontally on top of each other or with the tip vertically downwards beside each other So far it is not known whether the method of storing - horizontally or vertically - influences storage behaviour

The trench silo cum be built underground or so that put of the store is above the ground. It is covered with straw or similar materials. In some cases a layer of earth is also added. This type of storage system cum mainly be found in regions with a pronounced dry season

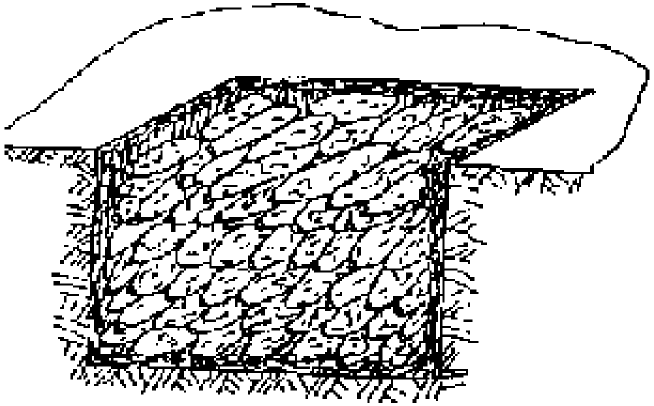

Fig.1: Storage of yam tubers in trench silos (Source: NWANKITI and MAKURDI, 1 989)

The trench silo provides protection from respiration and transpiration weight losses of the tubers. A disadvantage is the lack of ventilation and the direct contact of the tubers. This causes the stored produce to become warm and thus promotes the formation of rot (NWANKITI and MAKURDI, 1989). The contact existing between the tubers promotes the spread of rot within the silo. The closed structure of the trench silo does not allow regular checking of the produced stored. Apart from this, the silo offers good refuge for rodents who cum cause the corresponding damage to the stored produce (ONWUEME, 1978).

4.6.3 Storage of yam tubers in heaps on the ground

According to this method of storage the yam tubers are piled on a carpet made of dead yam climbers into a heap. This normally happens under a tree providing shade and the heap is covered with maize or millet stalks or similar materials (FAO, 1990).

This method of storage can be erected without any costs The shady tree

somewhat balances out the temperatures occurring throughout the day and provides certain protection against overheating of the produce.

This storage is badly ventilated. As it is closed, the produce cannot be checked regularly. This promotes rapid spreading of rot which means that storage duration is strictly limited The stored produce is also damaged by insects and rodents which can hide themselves very well in the store (NWANKITI and MAKURDI, 1989)

4.6.4 Storage of yam tubers in clamp silos

In Nigeria, attempts have been made to store yam tubers in clamp silos. The technique of building the clamp silo was oriented to experience gained in northern Europe (WAITT, 1961). The results of storage in clump silos in Nigeria were contradictory. They were better for some varieties of yam in comparison to the traditional yam ban but were worse for others. The clump silos met with little acceptance for the storage of yams among the local population for socio- cultural reasons (COURSEY, 1967).

4.6.5 Storage of yam tubers under a conical protective roof made of maize or millet stalks

This type of storage is often erected under a shady evergreen. It consists of a conical protective roof which can also be lengthened as e.g. in Fig. 2. The tubers lie on top of each other under this protection (N'KPENU and TOUGNON, 1991)

This method requires no financial investment. The additional work input required is also limited. The shady tree makes temperature fluctuations throughout the day

milder and the light protective roof allows sufficient ventilation (ibid.)

Problems arise with the possible entry of insect pests and rodents in addition, there is also the risk of wild and domestic animals damaging the roof construction in their search for food and causing damage by feeding on the tubers which can lead to rot As the tubers are piled on top of each other and the roof completely covers the tubers, it prevents regular visual checking of the produce stored

Fig. 2: Example of storage for yam tubers with maize and millet stalks (Source: ASIEDU, 1986)

4.6.6 storage of yam tubers in mud huts

This type of storage is often encountered in the savanna areas of the Yam Belt -i.e. in regions with a pronounced dry season (NWANKITI and MAKURDI, 1989) They have firm walls erected in the traditional mud style The roof consists of grass or other plant materials The construction is generally oriented to the particular regional architectural customs

The yam tubers are piled on top of each other in the hut The mud hut provides very good protection from rain and direct sunlight. With the roof made out of plant materials, this method of mud construction evens out temperatures.

The lack of ventilation and the piling of the yams are problems here. Both promote the formation of rot and the stored yams can only be checked with difficulty (ibid).

To build the mud hut requires a relatively high input of capita and labour However, the hut acknowledges this by having a low degree of maintenance need and a service life of 20 - 30 years (N'KPENU and TOUGNON, 1991).

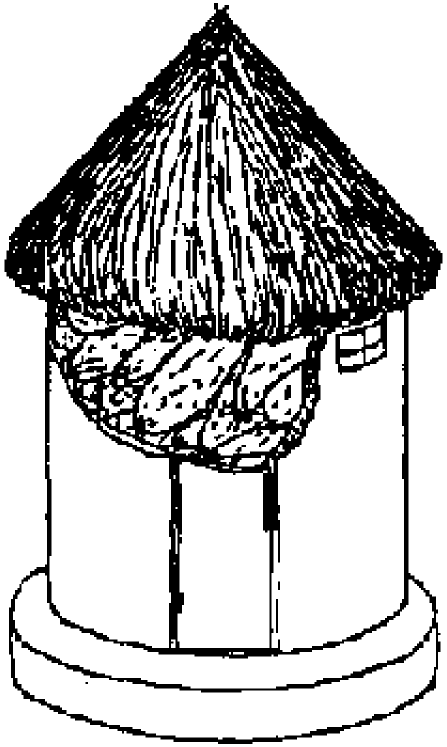

Fig 3: Traditional mud hut for the storage of yam tubers (Source: NWANKITI and

MAKURDI, 1989)

4.6.7 The storage of yam tubers in the yam barn.

This system of storage is the most widespread among traditional yam farmers in West Africa. A yam barn consists of vertically erected wooden posts of about 3 meters in length and set at a distance of 50 cm to each other The vertical posts are stabilised by attaching horizontal posts to them Frequently trees which are still growing are integrated into the storage system for static reasons and also to provide natural shade (NWANKITI and MAKURDI, 1989)

The yam bum is erected in the open air and it is important that there is sufficient shade available. To provide this, a roof is sometimes made of palm leaves, or evergreens are used as natural shade. The bum has to be constructed in an airy spot so that the surplus humidity in the air occurring from respiration and transpiration of the tubers can be emitted Sufficient ventilation also reduces the risk of the tubers heating and thus limits weight loss due to respiration and transpiration (ONWUEME, 1978).

The yam tubers are tied above each other to the vertical posts - mostly using plant fibres - starting from the bottom.The farmers use a particular method of tying for this (NWANKITI and MAKURDI, 1989)

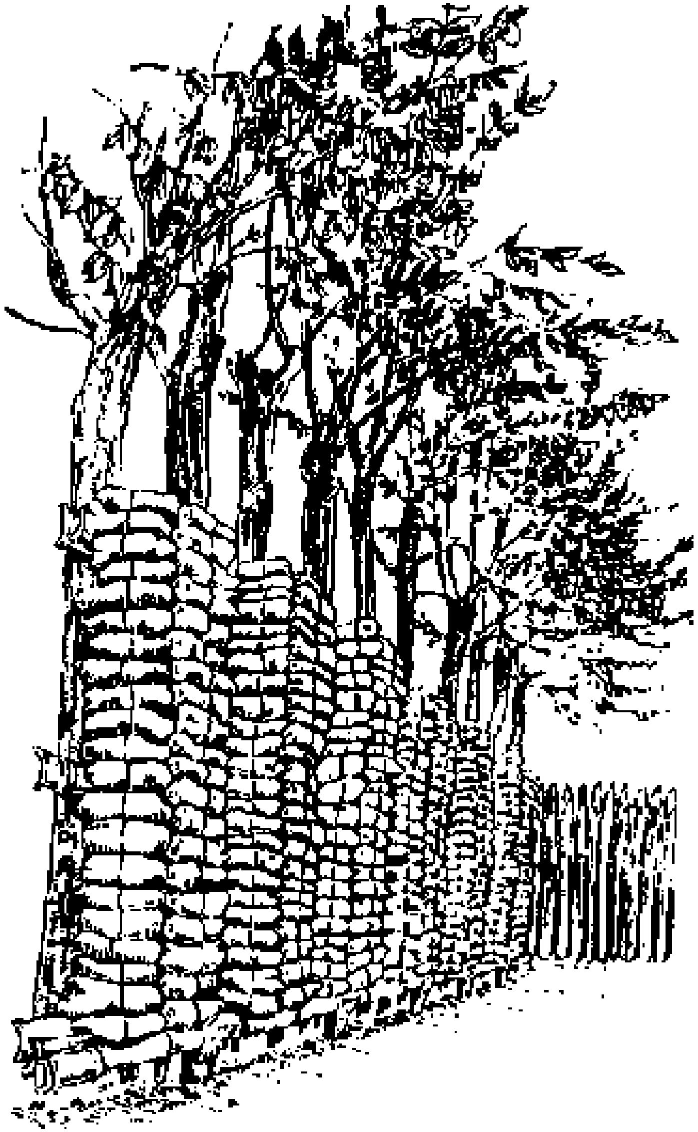

Fig 4 yam bum with living trees to provide shade (Source: WILSON, undated)

The yam bum is a well-aerated storage system which is easy to check. Germs and rotting tubers are easily removed This system shows no problems during the dry season. During the rainy season the high humidity however leads to rapid rotting

of the tubers (ONWUEME, 1978).

The construction of the yam barn for use over several requires not only a high input of costs (wood for construction) but also of work, Repair work normally occurs annually Putting the tubers into storage, i.e. tying each individual tuber up, is a great amount of work The tubers are often injured during tying which promotes the formation of rot (NWANKITI and MAKURDI, 1989) The traditionally open method of building provides no protection from insect pests or termites Often no measures are taken to protect the produce from rodents.

Fig. 5 The technique of tying the individual yam tubers up in the yam barn (Source: ASIEDU, 1986)

4.7 Measures to improve traditional yam storage

Any measures to improve existing storage structures have to be in harmony with

the relevant reasons and purposes for these improvements must not have a negative effect on the socio-cultural symbolic character which many storage systems have in addition to their purpose of providing protection. Furthermore, measures towards improvement have to be economic from viewpoint of the farmers and must not place excessive demands on his resources (e.g. work and d capital).

The suggestions made below primarily serve to improve the traditional storage structures and methods. The basis for the suggestions towards improvement derives mostly from experience gained by the yam farmers themselves or experiences shared by these. The results of research are also taken into consideration as far as these appear suitable for use by smaller farmers

In addition to measures towards improving traditional storage structures new, extensively technical solutions were worked upon These include systems like storing the yam tubers m refrigerated storage facilities or in a controlled atmosphere and the use of radioactive radiation to inhibit germination and to prevent rot (DEMEAUX and VIVIER, 1983)

These processes are not to be discussed in greater depth here. Nevertheless, these technically extensive processes offer bases for the reduction of storage losses caused by germination transpiration and respiration and thus involve the central problems of storing fresh yam tubers. The high degree of technical requirements and the investments required of the farmers do not allow these processes to be successfully applied to the level of the small farm producers at present. In view of a demand which is becoming more and more centralised in African countries due to advancing urbanisation, these systems which could contribute to food self-

sufficiency should not be completely disregarded.

4.7.1 Care in harvesting transport and storage

Although the yam tuber looks very hardy, the epidermis car be easily injured. Each injury, regardless of its size, increases the risk of infection and d thus early deterioration due to rot (FAO, 1981). For this reason, it is absolutely essential to keep the risk of injury as low as possible if storage is to be long-term and successful (PLUMBLEY, 1 982).

To reduce the risk of injury, the yam tubers have to be harvested with great cue and caution. This is indubitably made more difficult by the size and irregularity of the tubers (SADIK, 1987). Tubers are often also damaged during transport For this reason, the tubers should be moved very carefully and not thrown. High piles on transport vehicles increase the risk of injury stemming from pressure and should consequently be avoided. A further cause of injury is when they are heaped and tied when the tubers are stored in the yam barn.

Many farmers are not aware of the relationship between injury and tuber rot. For this reason, the farmers should be sensitized to this. It should also be made clear how the success of storage quite decisively depends on the condition of the stored produce at the time of puffing these into storage (SADIK, 1987).

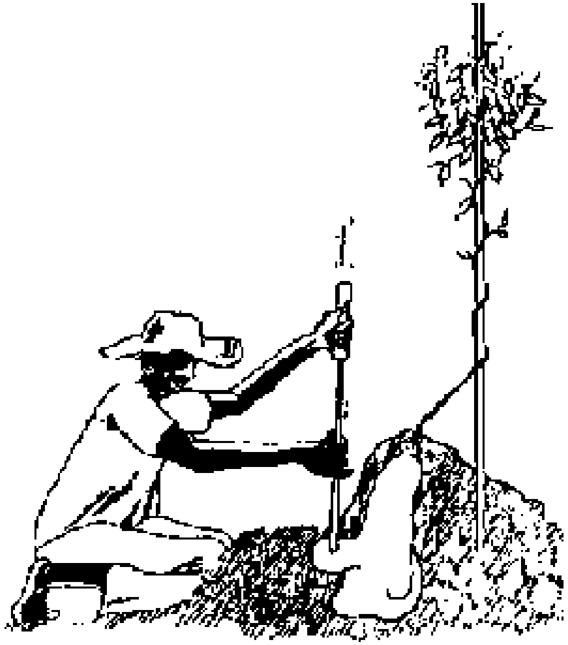

Fig. 6: Example of how yam tubers can be injured during harvesting (Source: WILSON, undated)

4.7.2 Curing

Curing allows injured fruits marked by a high water content to heal themselves. The process was initially tested on potatoes and sweet potatoes but a positive effect was also shown for yams (DEMEAUX, 1984). So that the healing process for the wound car occur and the wound is not only dried out it is essential for temperature and humidity to be increased

Increased temperature and humidity stimulate the yam tubers to from cork cells which can hermetically close the lesions The cork cells are formed in the cork cumbium and then make their way to the wound areas which they close with several layers of wound periderm (BAUTISTA, 1990)

To form the wound periderm certain metabolic processes are necessary These processes use energy which is gained by expiring starch stored in the tuber. During the respiration processes, water, carbon dioxide and heat are released into the environment (BAUTISTA 1990) Thus the healing of wounds is always connected with a certain loss in tuber weight.

The losses in weight depend on the "curing conditions", i.e. on temperature, humidity, duration of the process and the size of the wound Experiments in Togo (temperature 35 - 40°C, relative humidity 80 - 95%, duration of treatment 3 days) showed losses in weight due to curing of approx. 1 % of he fresh weight of the tubers (FAO, 1990).

Curing car seal a wound so that neither the water in the fruit can emerge (certain weight loss and shrinking of the tuber) nor can rot enter the tuber. The germination capability of the tuber is not affected by this process so that tubers which have been treated can be used for vegetative propagation.

Healing the wound should be carried out directly after harvesting the tubers (BOOTH, 1978) Clean and smooth cuts heal best of all. injuries due to squashing do not normally heal but remain as a centre of infection (COURSEY, 1982) All wounds, squashed areas and other injuries should consequently be cleanly cut out.

There are various processes for healing wounds. These differ in their technical methods, their demands on the climate and in the duration of treatment (FAO, 1990; DEMEAUX, 1984; BEEN et al, 1977).

Curing under a jute sheet or under jute sacks is a process developed by the FAO in Togo (FAO, 1990). The tubers, after the appropriate preparation are piled horizontally over each other and covered with a thick layer, about 15 cm, of straw. The whole pile is then covered with a jute sheet or with jute sacks.

This process is very costly since approx. 50 US Dollars have to be estimated for the sacks (FAO, 1990). If the process were carried out with a sheet, the costs would be even higher. The management of this process is also demanding since keeping the temperature (35 - 40°C) and the humidity (80 - 95%) is quite difficult. Cost and management requirements give rise to the question as to whether this process can at all be adopted by the farmers.

Fig 7 Healing wounds under a sheet made of natural fibres (Source: WILSON, undated)

Another process is the so-called "pit-curing system" which is widespread among yam farmers in Bendel State in Nigeria. For this process, a pit of approx. 2.5 x 1.5 x 1 metre is excavated and the bottom is covered with sawdust. The tubers are put in and covered with a thin layer of soil (NNODU, 1987).

This process shows its best effect at a temperature of 26°C and a relative humidity of 92%. Duration of treatment amounted to 11 and 15 days. In comparison to untreated tubers which were all affected by rot after 4 months of storage in a yam

barn, the cured tubers showed only 53% and 40% rot (duration of curing: 11 days and 15 days respectively) (NNODU, 1987).

To define optimum "curing conditions" is very difficult and is influenced amongst others, by the type of yam, the type of wound and the degree of tuber maturity (BOOTH, 1978). It is thus not surprising that the statements on temperature, relative humidity and duration of treatment greatly vary in the relevant literature (DEMEAUX, 1984; FAO, 1990).

Farmers prefer curing processes with low additional costs and a low input of extra work which effect a substantial improvement in the storage behaviour and which are simple to handle. Future activities regarding improvements in the curing process should be oriented to these requirements of the farmers.

The work of BEEN et al. (1977) also goes in this direction. These determined that tubers which had only been placed in direct sunlight for a certain time showed similar storage behaviour to tubers which had been subjected to more extensive treatment. It must be remembered here that the extensive curing processes require a climate which also promotes the reproduction of pathogens and which consequently, under some circumstances, could have a counterproductive effect (ONWUEME, 1978).

Table 9: The influences of curing processes on the storage losses of D. rotundata

Climatic	**Weight loss after**	**After 70 days uncontrolled storage**	
conditions	**treatment in %**	**Weight loss %**	**Germination %**
Direct sunlight		11.0 22.5	77

Direct sunlight		11,0 22,5	77
26°C/66% RH		9,1 35,5	33
30°C/91% RH		2,1 36,1	50
40°C/98% RH		4,3 20,9	73

Source: BEEN et al., 1977
(modified)

4.7.3 Influencing dormancy

As already stated earlier, the length of time the tubers can be stored strongly depends on the length of dormancy (cf. 3.5.1). Prolonging dormancy is thus essential in extending the storage of fresh yam tubers.

The duration of dormancy can be influenced to a certain extent by temperature and relative humidity. Low temperatures and low relative humidity rates prolong dormancy (PASSAM, 1977). The possibilities of changing the temperature and humidity to influence dormancy are limited as the tube tissue is destroyed when the temperature falls below 15°C (ibid.). A humidity which is too low also hinders storage quality as early drying of the tubers is induced by this.

Influencing the storage climate by external energy (refrigeration) is restricted economically due to the low product value of yams and the high energy costs.

Another possibility to influence dormancy is by using chemical agents to inhibit germination like are used, for example, in successfully storing potatoes (PERLASCA, 1956). When applied to yams, the substances used for potato storage

showed no effect. The reason is that yams, in contrast to potatoes, do not germinate until late and then not in the epidermis but in the cell layers below this. The agents applied in storing potatoes could have a counterproductive effect on yams as they impede the healing process and can promote the formation of rot (DEMEAUX, 1984).

Experiments to influence germination with natural and synthetic growth hormones showed positive beginnings. Amongst others, gibberellic acid, a synthetic hormone available in several compositions, and batatasins were tested. The latter are natural growth hormones which occur, amongst others, in different Dioscorea varieties. Batatasins applied endogenously showed no or a very limited effect on dormancy (PASSAM, 1984) so that further progress in this direction is doubtful.

Experiments with gibberellic acid were positive in some cases, i.e. dormancy was clearly prolonged by the effect of this hormone. If gibberellic acid is applied to the foliage prior to harvesting, dormancy is only extended for Dioscorea esculenta. Applied to Dioscorea alata, gibberellic acid showed no effect at all (WICKHAM, 1984,a). If gibberellic acid is applied after harvesting the dormancy of Dioscorea esculenta as well as Dioscorea alata can be extended. Use on Dioscorea bulbifera remained without effect (WICKHAM,1984,b).

Table 10: The effect of various chemical growth regulators (germination inhibiting agents) on the storage quality of yam tubers

Yam variety	Chemical agent	Effect on the storage quality
D.alata	methyl-a-NAA	+ 1,5 - 2 months
	chlorethanol	promotes germination

	gibberellic acid	+ 4 weeks
D. rotundata	methyl-a-NAA	no effect
	gibberellic acid	no effect
	IAA	no effect
	kinetin	no effect
D. esculenta	gibberellic acid	+ 6 weeks

Source: PASSAM, 1982 (modified)

According to WICKHAM (1984,b) the best effect occurs when the tubers have been treated for 22 hours in a solution of 150 mg/litre gibberellic acid. Other authors recommend other concentrations in some cases for the same agent (MARTIN, 1977; DEMEAUX and VIVIER, 1984). According to OSIURO (1992), dormancy can be extended for longer, the higher the concentration of the agent is.

Apart from the concentration of the agent, the point of time when it is applied is a critical factor in influencing the hormones for dormancy. MARTIN (1977) defines application towards the end of natural dormancy to lengthen this, a fact which is disputed by WICKHAM (1984,a). For PASSAM (1985), the condition of the tuber is a decisive factor in the effect of gibberellic acid. If gibberellic acid is applied to freshly germinated tubers this will promote the formation of germs. If the germs are removed prior to application it will delay re-formation of germs. The most favourable time for the application of gibberellic acid according to DEMEAUX and VIVIER (1985) is just after harvesting.

According to research findings so far, it can be assumed that gibberellic acid delays the formation of genes, i.e. prolongs dormancy However, there is a necessity for application methods, times and agent concentrations to be clarified. Only when these points have provided precise results and the economic efficiency of the process has been proven can recommendations on practical application be expressed.

Until such information is available, the germs should be removed manually. Since too frequent removal of the germs stimulates re-growth, the germs should not be removed until these have attained a length of approx. 50 cm.

4.7.4 Influencing the storage climate

During storage, certain metabolic processes have to take place so that the tuber retains its viability and reproductive quality. The intensity of respiration and transpiration is partly dependent on the "storage phase" at which the tuber is (cf. Chapters 3.5.2 and 3.5.3). In addition, the storage climate, i.e. temperature and humidity, have an effect on this. These two determinants in storage behaviour are not given quantities but can be manipulated by means of certain methods.

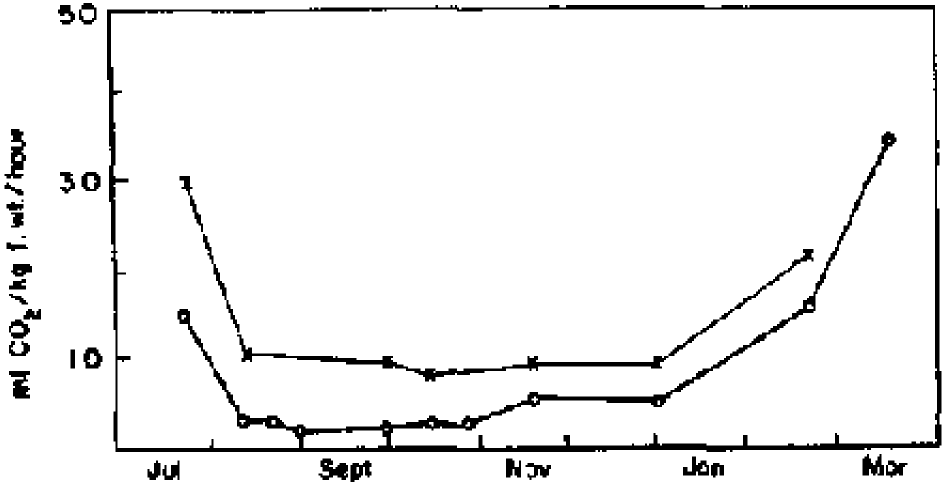

Fig.8 Respiration of yam tubers during storage at varying temperatures (0 = at 25°C, X = at 35°C storage temperature) (Source: PASSAM et al., 1978)

4.7.4.1 Influencing the storage temperature

In general, it can be determined that a longer storage period is possible at lower temperatures. At lower temperatures, respiration is lower and simultaneously, the formation of germs is delayed (DEMEAUX and VIVIER, 1984).

For many tropical fruits there is a "critical" temperature. Below this, an irreversible change in tissue occurs resulting in rapid deterioration of the fruit. The critical temperature for tropical fruits, also referred to in literature as causing the irreversible "chilling injury" alteration to the tissue, is well above freezing point. For yams, depending on the variety, it is between 13 and 15°C (DEMEAUX and VIVIER, 1984) Other authors state the critical range as being between 10 and 12°C (DEMEAUX and VIVIER, 1984).

Consequently, a reduction in temperature to improve the storage quality of yams

is very limited and this should not fall below 15°C. Without using external energy for cooling even this value can hardly be retained under tropical conditions. The use of external energy also making the construction of closed and insulted storage structures essential, cannot be considered a possibility to improve the storage of yams on a small-farm level for reasons of cost.

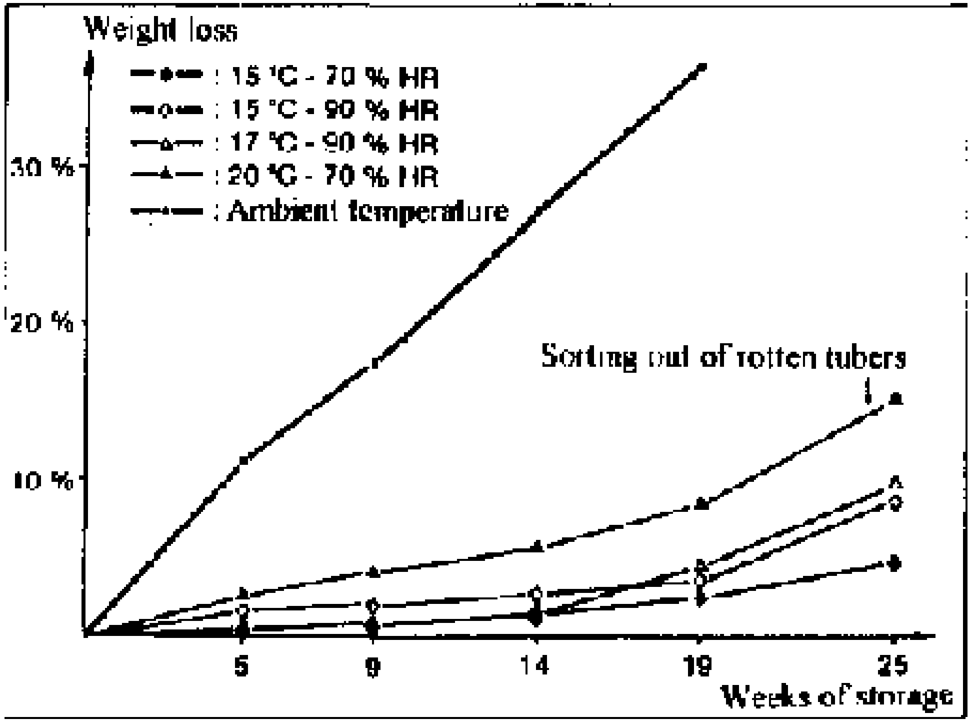

Fig 9: The influence of temperature and air humidity on the losses in yam tuber storage (Source: DEMEAUX and VIVIER, 1984)

Even low reductions in temperature lengthen the period of storage for yams. For this reason, all possibilities available for this which are economically feasible should be made use of Initially and primarily to be thought of here are simple changes in the construction of traditional storage structures to take advantage of

the natural temperature fluctuations between day and night. Planting shady trees and the use of air currents can also lead to a noticeable reduction in storage temperatures and thus provide a contribution to improving the storage climate.

4.7.4.2 Influencing humidity of the air

There is an exchange of water vapour between the stored produce and their environment for the purpose of balancing out the moisture content of the produce and its surroundings. Dried crops e.g. cereals, tend more to re-absorb moisture from the surrounding air. Crops like yams which have a high moisture content tend to emit moisture to their environment during storage.

Loss of moisture from stored yams is not desired since this leads to economic loss (loss in weight and shrinking of the tubers) without improving storage quality. Consequently, the air in storage should have a humidity rate at which the exchange of water vapour is minimal. At a storage temperature of 26 - 28 °C which can be assumed typical for West Africa, a relative humidity of 70 - 80% leads to an equilibrium, in which the exchange of air between the tuber and its surroundings is very low.

With these storage conditions, the tuber retains the properties which define its quality like colour, aroma, flavour and chemical composition. At a higher relative humidity, there is the risk of water vapour condensing which promotes the formation of mould on the tubers.

When considering measures to influence humidity, only those should be taken into account which are technically and financially feasible for the target group of

farmers. In the foreground here are alterations in construction which promote the exchange of air and thus remove superfluous air moisture from storage. The changes in construction can be supported by selecting a location which encourages air exchange.

4.7.4.3 Promoting ventilation

Normal atmospheric air consists of 78% hydrogen, 21% oxygen, 0.03% carbon dioxide and a varying content of water vapour.

The supply of oxygen from the air is essential for the metabolic functions to preserve the life of the tuber. At the same time the tuber releases water vapour and carbon dioxide. If the composition of the atmosphere in storage deviates from the normal state of the air as a result of the metabolic functions this can have an unfavourable effect on the condition of the stored produce.

Excessive air moisture which can condense if the temperature falls, promotes the formation of rot. Very low concentrations of oxygen prevent respiration and promote an undesired fermentation of the tubers in storage. Increased carbon dioxide and ethylene concentrations where yams are stored are not desired either. Increased carbon dioxide concentrations cause destruction of the tuber cell structure. Ethylene is a growth hormone which promotes germination (BATISTA, 1990).

For the above reasons it becomes clear that changes in the composition of the atmosphere in storage are not desired as these can have a negative effect on storage. To avoid undesired changes in the atmosphere the store must be

sufficiently ventilated. Ventilation is not only for the purpose of gas exchanges between the store and the environment but also affects the temperature in storage.

Controlling ventilation is not simple and easily leads to counterproductive effects. If, e.g. the store is ventilated during the day, this can, at raised temperatures, lead to undesired heating of the stored produce. Inadequate ventilation at very low humidities promotes drying out of the tubers in storage. The store should consequently be ventilated at night as far as possible since temperatures are lower during this time and the relative humidity is normally higher (SADIK, 1987).

As with other improvement measures, the improvements in ventilation should be as simple as possible to carry out and not incur any additional cost. Where storage facilities are to be newly erected, locations allowing natural ventilation by means of air currents should be selected. Apart from this, the tubers should be stored so that ventilation is not hindered. Storage in huge heaps and in trench silos are consequently not suitable to meet the demands of sufficient ventilation.

4.7.4.4 Providing shade for storage facilities

On the one hand, the direct effect of sunlight on stored produce increases storage temperatures. On the other hand, the formation of germs is promoted by this. For this reason, the store should be sufficiently m the shade.

Sufficient shade can be attained by constructions where storage structures are covered by a roof. Roofs should be made of plant materials available locally for cost reasons but also due to the high heat insulation provided by these. A roof not

only keeps the rays of the sun out but also protects the stored produce from rain showers which promote the formation of rot.

In addition to building roofs, natural shade should also be made use of, as protection for the produce e.g. evergreen trees. When mounting roofs for shade and taking advantage of natural sources of shade, it must be observed that the ventilation of the store is not affected negatively.

4.7.5 control of rot

As already stated, rot is caused particularly by fungus and bacteria pathogens. These can however only penetrate the skin of the tuber through damaged spots, like injuries, lesions and holes made by nematodes.

An important precaution is consequently to minimise the risk of injury to the tuber during harvest, transport and storage by treating it carefully. Tubers already showing rot at the time of being stored should be put to some other purpose.

The danger of rot can be reduced by curing processes (cf. 4.7.2). In this way wounds are closed so that agents causing rot can no longer enter the tuber. In addition to curing, the wounds can be treated with traditional means like ash and limedust (ONWUEME, 1978).

Since rot can be passed from tuber to tuber the stored produce must be checked on a regular basis so that infested tubers can be removed from the store in good time.

Treating the tubers with fungicides is also a measure which can be used to control

rot. Satisfactory results have only been achieved with thiabendazol and benomyl (DEMEAUX and VIVIER, 1984). These substances only have a low degree of toxicity and remain locally in the tuber skin, i.e. they do not move into the flesh of the tuber (DEMEAUX and VIVIER, 1984).

Treatment with fungicides is recommended as a bath. The concentration of the agent is stated as 250 - 2500 ppm at a treatment duration of 2 - 30 minutes (ibid.). It is considered necessary that further experiments to define the treatment with fungicide be carried out in view of the wide range of agent concentrations.

To avoid subsequent damage but also to achieve the appropriate effect, the treatment with fungicide requires a very precise procedure. This necessitates a high degree of extension and backstopping for small African farmers in the use of fungicides.

4.7.6 Control of nematodes

The control of nematodes is simultaneously also a precautionary measure against rot agents who follow the nematodes and often cause greater damage than the nematodes themselves.

Nematodes as parasites on roots and tubers are spread by plants which are infested. For this reason, only plants which are free of nematodes should be used for vegetative propagation.

As nematodes are also freely existent in the soil the relevant crop rotation (long periods between the planting of two yam crops) can reduce the pressure of the pests. To qualify this, it must be said mat most nematodes which are parasites on

yams also have other host plants. Control of the nematodes by appropriate rotation is thus made more difficult.

Measures like chemical control or the treatment of tubers with hot water (CENTRE FOR OVERSEAS PEST RESEARCH, 1978), seem less suitable for use on small farms. On the one hand the processes are not yet mature, and on the other the essential financial and labour inputs are too high to encounter sufficient acceptance.

4.7.7 Control of insects damaging stored produce

Measures to control insects causing damage within yam stores basically have two purposes: firstly the damage caused by insects (eating and loss of quality) are to be avoided or at least reduced. Secondly, control measures are to avoid secondary damage caused by rot pathogens which can penetrate the tuber through the injuries to the epidermis caused by insects.

As precautionary measures, separate storage of infected and healthy tubers can be considered. In some cases, e.g. with the yam moth, this is difficult since infestation cannot always be observed externally. For hygienic reasons, all parts of the tuber which are infested by insects should be burned and not kept in the proximity of the store (WILSON, undated).

The types of storage also have an influence on the infestation of the produce by insects. SAUPHANOR and RATNADASS (1985) report that tubers stored in trench silos are not infested by moms or pyralid moms which can cause great damage in storage above ground. As storage structures are also selected on the basis of other criteria no particular type of storage can be recommended at this point to

reduce storage losses due to insects.

The control of scale insects can be carried out with pyrimiphos-methyl in a concentration of 25 g per litre water. The tubers remain in this solution for 10 minutes and are subsequently dried (SAUPHANOR and RATNADASS, 1985).

Deltamethrin is recommended for the control of tineid and pyralid moths. The product is applied in concentration of 2.5 grammes per 100 litres water as a dip with a duration of 10 minutes. If infestation occurs this should possibly be repeated. For economic reasons, the agent can also be sprayed onto the stored produce (ibid.).

The statements on chemical control of insect pests on stored yams in the literature available are very limited. Further investigations are necessary or should be repeated to define suitable insecticides, concentrations, application techniques and the time of application.

Farmers tend to take the problem into their own hands when a certain intensity of damage is evident. When this happens, chemical products which are not appropriate are often used, and which can lead to food poisoning in some cases if the yams treated are eaten. The products are often improperly concentrated and applied. In view of possible mistakes in application but also in view of the possible economic damage the insects can cause to yam storage, clear recommendations should be compiled for application during chemical control.

The matter of biological control of pests has hardly been mentioned so far. According to SAUPHANOR and RATNADASS (1985), Phanerotoma leucobasis

Kriech is a natural enemy of E. vapidella whose eggs it eats. In how far there is a basis for biological control here will have to be a question for future research.

4.7.8 Measures for protection from mammals

To protect stored produce from mammals, measures depending on the species and on the type of storage have to be undertaken.

Domestic animals can mostly be kept away from stores by fences. Stores erected on stilts, e.g. a platform store, due to their construction provide good protection from domestic animals which could damage the stored produce. These stores can be quite easily protected from rats. Metal funnels are mounted on the stilts with the wide end downwards at a height of approx. 100 cm Rats and other rodents are not able to get past these obstacles.

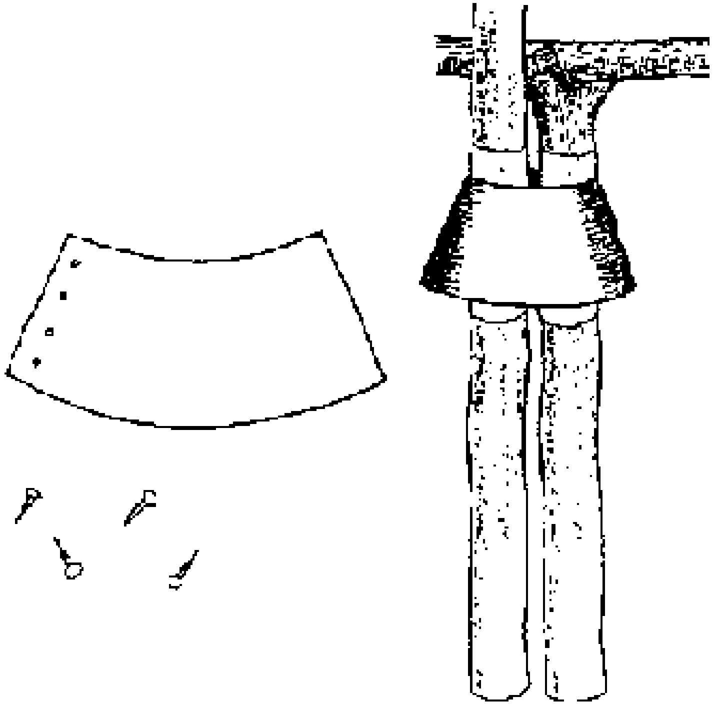

Fig 10: Material for and mounting of a device to provide protection against rodents (Source: PROJET BENINO-ALLEMAND undated)

4.7.9 The improved traditional yam barn

In view of reducing losses and long storage, the yarn barn shows the best results in comparison to other storage systems widespread in West Africa. This is one of the reasons for the yam barn frequently being selected as the basis for improvement measures to traditional systems of storage on which this work is based. Without changing the type of storage some measures and extensions to the construction can be carried out and can lead to a considerable improvement of the barn.

Improved storage of fresh yam tubers begins during harvesting. Injuries should

be avoided as much as possible as these constitute doors for rot viruses. For this reason, harvesting, transport and storage have to be carried out with as much care as possible (NWANKITI et al., 1989). When transporting over longer distances, the tubers should not be piled up too high or this will quickly lead to injury to the epidermis and the formation of bruises.

Immediately after harvesting, the tubers should be subjected to curing (cf. Chapter 4.7.2). Bruises and lesions on the tubers should be cut out as smooth wounds heal better. For hygienic reasons the soil clinging to the end of the tubers should be removed. In how far treatment of wounds with ash or other traditional means improves storage ability will have to be clarified by further experiments. Prior to storage, the remains of the previous year's harvest should be removed and burned as this can constitute a source of infection.

The traditional yam barn has some disadvantages. Consequently, the following improvements should be made.

- A roof construction similar to a hut and made out of local materials like straw, palm leaves etc. should cover the barn. A roof made of plant materials not only provides sufficient protection from sunlight or rain but also regulates temperature fluctuations due to its insulation features. The roof should have a height of at least 2.50 metres so that ventilation of the barn is not restricted (FAO, 1990).
- The barn should be made safe from rodents and domestic animals. There are several possibilities here. It can be surrounded by a fence made of oil barrels which have been cut open. Possible would also be a wall which, however, would have to be at least one metre high. As rodents can easily overcome a wall (in contrast to an oil barrel barrier) the space between the top of the wall and the

roof should be protected with fine wire mesh. It is important that the barn is fitted with a door which closes well and will also prevent theft.

- In the modified yam barn the tubers are stored on multi-level shelves. The shelves can be constructed of various locally available materials as far as these provide sufficient support. The lowest board should be about 50 cm above the ground so mat no moisture is taken up from the ground. The shelves should be arranged so that a visual control of the tubers is possible quickly and all around. This is facilitated by the tubers only being stored in two or three layers on each shelf. It will also prevent too much weight exerting pressure on individual tubers and thus reduces the risk of bruising.

- The selection of the site is very important in making use of the advantages for the system. This should be chosen so mat natural air movements can be used for ventilation. The store should be set sideways to the main wind direction so that the natural movement of the air can be used to its full effect. Existing natural sources of shade, e.g. evergreens, should also be taken into account during selection of the site as the temperature in the interior of the barn can be considerably reduced by these.

The natural shade and its temperature reducing effect can mean too strong ventilation during the day. Consequently it must be ascertained mat not too much hot air enters the store as ventilation during the day.

The size of the store can be adapted to individual needs. There is no documented experience on costs for construction and maintenance of the yam barn. As local materials are mostly used, the extra financial means necessary should be limited in comparison to the traditional yam barn.

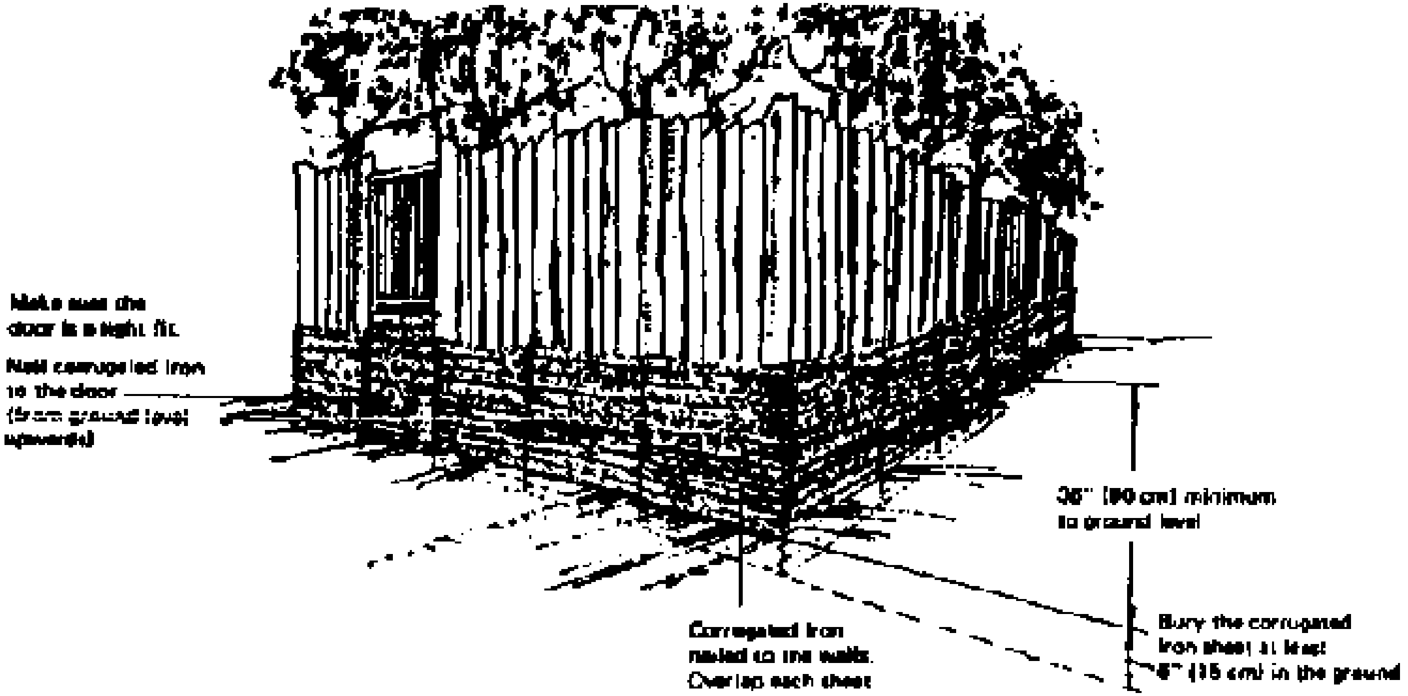

Fig 11 Example of a rodent-proof fence for storage of yam tubers in the yam barn and in similar storage systems (Source: Wilson, undated)

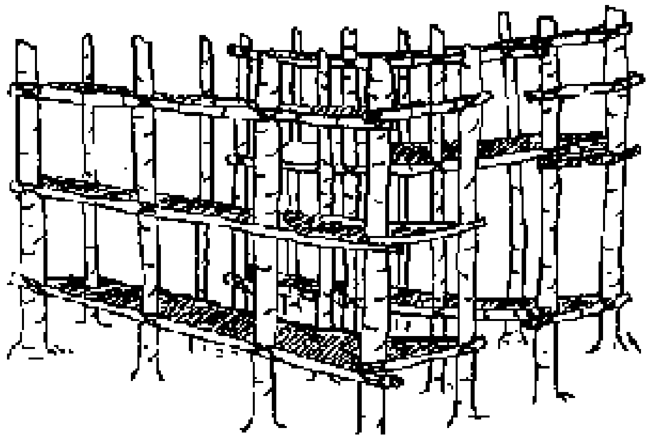

Fig 12 Simple shelves made of local materials for the storage of yam tubers (Source: NIGERIAN STORED PRODUCTS RESEARCH INSTITUTE 1982)

The use of germination inhibiting agents like gibberellic acid, treating the tubes with fungicides and insecticides can be considered as complementary means of improving storage systems. The lack of practical experience in the application of these prevent any concrete recommendations on the use of such products at this stage.

Regular inspection of the stored products is important for the success of storage systems. Rotting tubers must be sorted out and removed. Germs have to be removed regularly. The INPT (1988) recommends removing germs when these are approx. 50 cm long. Removing the germs too frequently induces the tuber to produce more germs.

According to investigations by NWANKITI et al. (1988), the improved yam barn can contribute considerably to reducing losses. The weight losses observed after six months storage in the traditional yam barn were 41.7%, in the improved yam barn these were 13.3% and with the improved yam barn with extra protection from rodents, 10.8%.

The results of investigations by NWANKITI et al. (1988) indicate that even simple improvements to the traditional yam barn can substantially reduce losses. For this, not all of the improvements mentioned above have to be carried out. Also individual improvements can clearly reduce losses. This means that improvements can be oriented to particular local conditions and requirements of farmers.

Considered macroeconomically, the improved yam barn leads to an increase in the supply of foodstuffs which can be produced on the domestic market. A contribution can be made to the balance of trade if the foodstuffs produced

substitute food imports.

For the farmer, improved storage means an increase in subsistence security. At the same time he gains larger scope for decisions on selling and is better able to take advantage of price movements to improve his income.

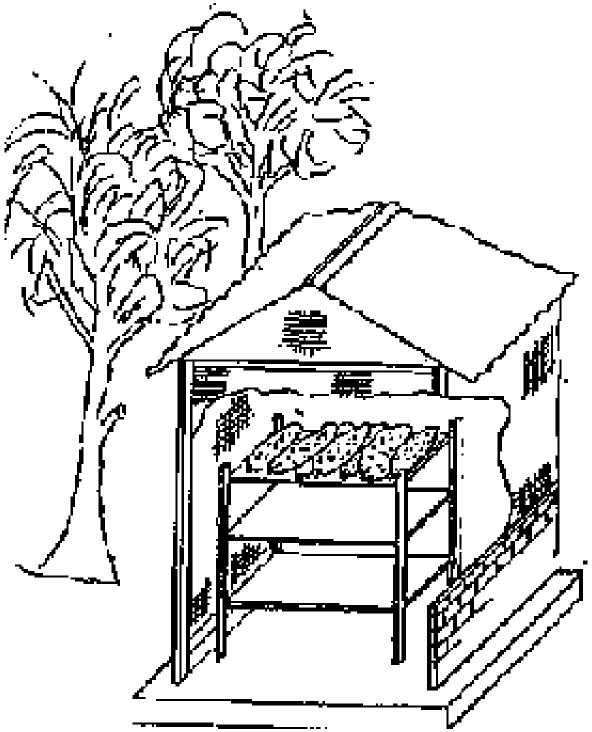

Fig. 13: Model of an improved yam barn with protective roof and walls (Source: NWANKITI and MAKURDI, 1989 (modified))

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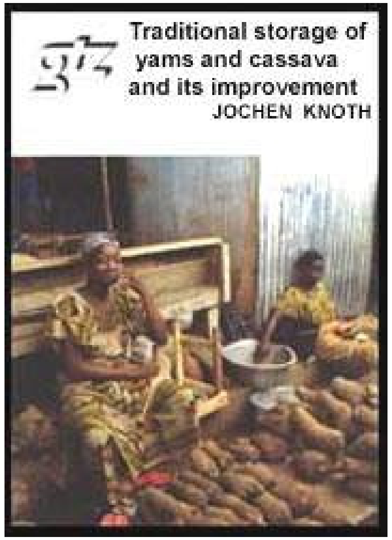
Traditional Storage of Yams and Cassave and its



Improvement (GTZ)

Traditional Storage of Yams and Cassave and its Improvement (GTZ)

5 Cassava

Cassava is a plant of the new world which originates in the northeast Brazil. Central America is assumed as another source (ONWUEME, 1978). Having begun with these two regions, cassava is now cultivated in all tropical regions of the world.

In contrast to yams, mere is only one species of cassava bearing the scientific name Manihot esculenta Crantz and belonging to the family of the Euphorbiaceae.

There is a wide range of cassava varieties. Individual varieties can be recognised by the leaf and root form, the duration of vegetation, the yield and the content of hydrogen cyanide. The latter constitutes the difference between the sweet and the bitter cassava.

The bitter varieties of cassava have a high hydrogen cyanide content which can amount to up to 250 mg pa kg fresh root (GRACE, 1977). To avoid poisoning, the roots have to be detoxified before consumption. The vegetation period for bitter cassava varieties lies between 12 and 18 months. After ripening, the roots can be left unharvested in the soil for a long period and will not spoil (ONWUEME, 1978).

The sweet cassava varieties only contain low quantities of hydrogen cyanide so mat detoxification prior to eating is normally not necessary. The vegetation period is relatively short at 6 - 9 months. The roots of this variety rot quickly if they are left in the soil after maturity.

The content of hydrogen cyanide is not constant according to the varieties, but is subject to fluctuation due to the environment. For this reason, the content of hydrogen cyanide is unsuitable as the only criterion in defining the varieties of cassava (ONWUEME, 1978).

Cassava is a perennial plant. Apart from for purposes of research and breeding, propagation is exclusively vegetative. In contrast to yams which are propagated via the tuber, the cassava can be reproduced by cuttings taken from the stalks of the plant. As the stalks, in contrast to the root, are used neither for consumption nor other economic purposes, the cost of propagating cassava where planting material is concerned, is practically zero.

5.1 The environmental requirements of cassava

Cassava is a plant of tropical lowlands. Its cultivation is restricted to regions between the latitudes of 30° north and 30° south It is most widespread near the equator between 15° north and south Since cassava is a short-day plant, the highest yield of roots is in this region.

Cassava finds the most favourable growing conditions in humid-warm climates at temperatures of between 25 - 29°C and precipitations of between 1000 - 1500 mm which ideally should be evenly distributed (ONWUEME, 1978).

In view of the climate, cassava has an enormous ability to adapt. There are locations in the Andes where cassava is cultivated at an altitude of 2000 metres. Cassava can even survive slight frosts although the plant then loses its leaves which grow again when temperatures rise. Where mere are high temperature fluctuations, the annual average temperature must amount to 20°C. With low fluctuations in temperature, 17°C is also sufficient for successful cultivation (COCK, 1985).

Cassava is able to survive longer arid periods. During this period, the plant loses all its leaves and suspends growth even of the thick roots. When precipitation again begins, the plant regenerates without any great loss in yield occurring. This ability is why it is particularly suitable for locations marked by indefinite and irregular precipitation.

Cassava likes light, sandy loam soils with medium soil fertility and with good drainage. Saline, strongly alkaline and stony soils, and soils with stagnant water are unsuitable for the cultivation of cassava. Stony soils inhibit the formation of the root tuber. Where soil fertility is concerned, cassava is easily satisfied. Even on very poor and acidic soils which are totally unsuitable for the cultivation of other plants, the cassava will still provide a relatively good crop. For this reason, the cassava is frequently grown on edge locations which can otherwise not be used arably. The low demands of the cassava mean mat it is often the last member in crop rotation.

5.2 The cassava root

The economically most important part of the cassava plant is the tuber-like thick

root. This develops from thin roots which take the nutrients out of the soil. Only a few roots per plant develop into tuberous, thick roots.

The thick root is connected to the plant by a short, wooden neck. It has a longish round form and can grow to between 15 and 100 cm and reach a weight of 0.5 to 2.0 kg.

The cassava root consists of three layers. The cork periderm and the cortex below this form the exterior protection for the root. Both cell layers are only a few millimetres thick. The central part of the root is a storage tissue where starch is kept. In the centre of the root there is a small vascular bundle running lengthwise. There are cells which can secrete latex in the storage tissue as well as in the cortex.

The thickening growth of the roots does not begin until the roots absorbing the nutrients have penetrated the soil to prepare the way. The arrangement of thick roots is influenced by how the cuttings are planted. If these are planted vertically, thick roots develop and lie close to each other like in a bundle. If the cuttings are planted horizontally, roots will form at each node. The thick roots then develop at some distance from each other at the nodes of the cuttings (ONWUEME, 1977).

The thick roots have no function in vegetative propagation which occurs through cuttings from the stalk. The reason why reserve substances accumulate in the thick roots has not been completely clarified. It can however be assumed that these reserves serve to help the plant survive unfavourable situations e.g., longer arid periods. This ultimately also defines the good resistance of cassava to dryness.

The thick root in a fresh condition contains approx. 62% water, 35% carbohydrates (mainly in the form of starch), 1 - 2% proteins, 0.3% fats, 1 - 2 % fibres and 1 % minerals (ONWUEME, 1977). In comparison to the yam tuber, the cassava root contains more energy but far less protein. An unbalanced diet containing only cassava can lead to deficiency. Deficiency and poisoning can also be caused by the high concentration of hydrogen cyanide especially when cassava is not processed or insufficiently processed before eating (.cf. Chapter 6.2).

5.3 Economic aspects of cassava production

Cassava was introduced to Africa in the 16th century and became established at various locations on the continent in the subsequent centuries. However, not until the beginning of the 20th century did cassava become extensively widespread and find a permanent home in numerous small farm systems. In some cases, cassava clearly took over from other staple foods e.g. bananas in East Africa and maize and sorghum in southern parts (LYNAM, 1991).

In Africa, but also on other tropical continents, cassava is mostly grown by small farmers. In Africa, only 10% of production reaches the market; 90% is cultivated as food for the producers themselves. Cassava provides central benefits particularly for subsistence-oriented farms from an economic aspect.

Cassava has a potential tuber yield of 70 tons per hectare and with this, has the highest output per unit area among all staple foods providing starch (COCK, 1985). Decisive for subsistence-oriented small farmers who avoid risks is the ability of cassava to provide secure yields of 7 - 9 tons of roots per hectare even on marginal and acid soils and under unreliable precipitation conditions (ONAYEMI,

1982). In addition, the annual fluctuations in the yield of cassava are among the lowest for all food crops (HAHN, 1987).

In comparison to other roots and tubers, the labour productivity of cassava is very high. For a yield of 10 tons per hectare, a labour input of approx. 120 days (manual phase) can be estimated (COCK, 1985). This corresponds to about one quarter of the work input required to produce the same quantity of yams.

After the plants have closed their leaves, cassava can be left to itself. On the one hand, a contribution is made here to evening out peak seasonal work (HAHN, 1987). On the other hand, this encourages the seasonal migration of male labourers in search of an income, without endangering the production of cassava.

Production input, e.g. fertilisers, plant protection and propagation, is very low. Fertilisers can be completely dispensed with without fear of losing any part of the yield (COCK, 1985).

The economic features and modest requirements of the plant are the reason for it being called a "starving plant". Cassava is able to provide secure yields on marginal sites and under unfavourable weather conditions which cause crop failure for other plants.

5.4 Causes of limitations to storage for fresh cassava roots

The starch-storing root of cassava is of no importance for vegetative propagation. This means that the cassava, in contrast to the yam tuber, has no period of dormancy which naturally favours storage after the harvest.

When the cassava root has been harvested, a rapid process of deterioration sets in after 2 - 3 days at the latest. This can be differentiated in two phases.

Primary deterioration comes from the central vascular bundle in the root. This begins to take on a dark-blue to black colouring starting from broken and cut surfaces. The adjacent storage tissue is also affected and the starch stored undergoes structural changes (PLUMBLEY and RICKARD, 1991).

Experiments have shown mat no microorganisms are involved in the change of colour. This is based on an endogenous oxidative process. The colouring can be delayed by cutting off oxygen, e.g. by storing the roots in a water bath (PLUMBLEY and RICKARD, 1991).

Secondary deterioration mainly results from microbial activities but can also be due to fermentation and softening of the root tissue (PLUMBLEY and RICKARD, 1991). Secondary deterioration is caused by rot viruses which can occur in very complex compositions and vary from location to location (ibid.).

Considered economically, primary deterioration is more significant than secondary deterioration. Discolouring parallel to primary deterioration causes a distinct decline in the value of the roots and makes them impossible to sell. For this reason, it is initially essential to develop processes which allow primary deterioration to be controlled.

5.5 Ways of and limits to. storing fresh cassava roots

The cassava roots deteriorate within 2 - 3 days of harvesting. This means a high selling risk for the seller as the produce becomes unsaleable after a short time.

The seller tries to compensate for his sales risk by asking the appropriate prices. This means mat urban consumers have to pay relatively high prices for fresh cassava roots (FAO, 1988).

The problem of the storage ability of fresh cassava roots is also known to the traditional producers in tropical America. These societies already developed processes during historical times to allow extension of storage (RICKARD and COURSEY, 1981).

Also various research establishments have concerned themselves with the specific problems around cassava and have searched for a solution on how to lengthen storage of fresh cassava roots. The most significant results of these efforts and traditional methods are described below.

5.5.1 Storing cassava roots in the soil after maturity

The method of leaving cassava roots in the soil after maturity is still widespread today. The roots can be kept in this way for several months without deteriorating.

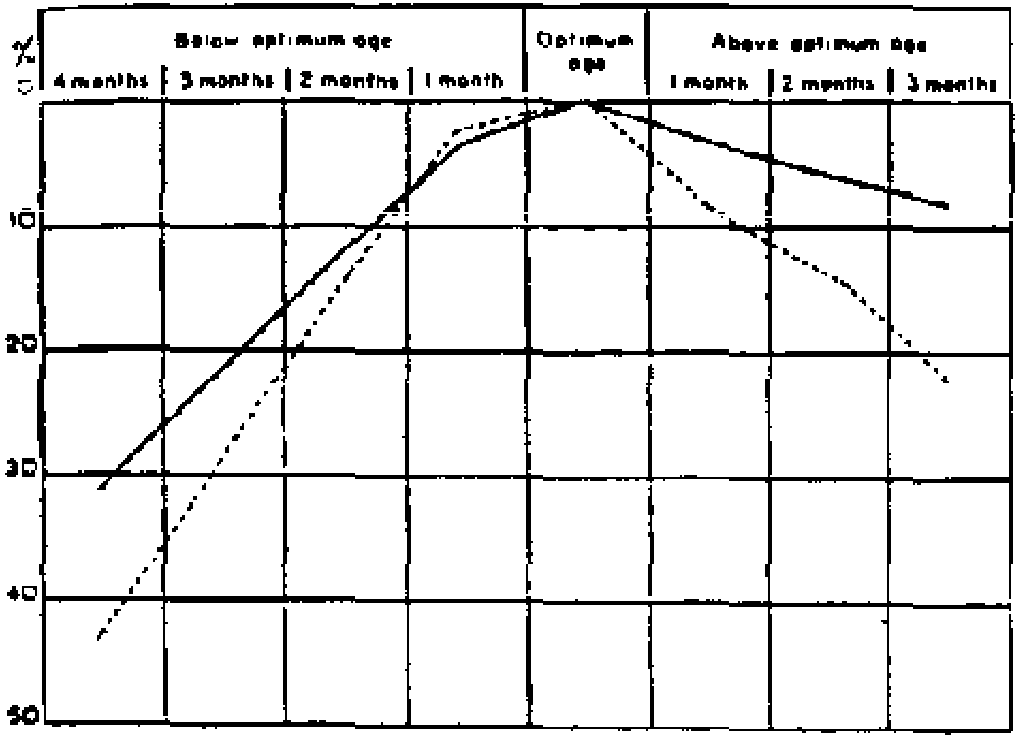


Fig 14 Yield loss for cassava when harvest takes place before and after the optimum time (in percent) (Source: GRACE, 1977)

With this method of storage, the rhythm of the harvest can be adapted to that of consumption. If the optimum harvest age has been missed, the root loses more and more substance and particularly starch, the constituent which defines its value (cf. Fig. 14), the longer storage is. At the same time, the root begins to become woody and impairments to the flavour occur (LANCASTER and COURSEY, 1984).

During storage in the soil there is also the danger of roots being infested by pathogens. Another disadvantage of this method of storage is that area which could be planted with other crops is occupied by storage (CHINSMAN and FIAGAN,

1987). Particularly in densely populated areas, this leads to shortage of land and increases production costs for cassava as the opportunity costs incurred have to be allocated to this method of production.

5.5.2 Traditional methods of storing fresh cassava roots

Freshly harvested roots can be buried in the soil to preserve them. This method is evidently oriented to the process of leaving ripe cassava roots unharvested in the earth (INGRAM and HUMPHRIES, 1972). It is said that by using this method in South America, cassava roots have been stored from one season to the next (RICARD and COURSEY, 1981).

Storage methods oriented to this process are widely distributed. In West Africa and India, roots which cannot be directly consumed or processed after the harvest are piled into heaps and watered daily. The roots can also be coated with a loam paste to attain a storage ability of 4 - 6 days (RICKARD and COURSEY, 1981).

In older reports on traditional storage methods processes are described which allow a storage of up to 12 months (RICKARD and COURSEY, 1981). However, there is justified doubt here as recent practical experiments have not been able to confirm these results. BAYBAY (1922) tested various traditional methods of storage on the Philippines. He came to the conclusion that all the traditional processes he had tested could only prolong storage by a few days. Only storage in trench silos showed a somewhat more favourable picture.

5.5.3 Storage of fresh cassava roots in clamp silos

The storage of fresh cassava roots in clamp silos was tested by the Tropical

Products Institute (TPI) and the Centro Internacional de Agricultura Tropical (CIAT) in Columbia. Setting up the clamp silos was oriented to traditional silos of the Indians and to experience gained in northern Europe with the storage of potatoes.

A more or less thick layer of straw is laid out on a dry area and the roots are piled on this in conical heaps. The heaps, weighing between 300 and 500 kg are covered by straw and soil and - as with potatoes - openings are left for ventilation (RICKARD and COURSEY, 1981). Storage periods of up to 4 weeks were reached with this method in experiments. Losses in weight and the formation of rot were low (BOOTH, 1976).

Controlling temperature for this method which should be below 40°C for successful curing of wounds and for storage, was difficult. Several structural changes towards improving temperature control were tested. These led to very varied and unforeseen results (BOOTH, 1976).

Although storage in clamp silos allowed a substantial lengthening of storage duration of up to 4 weeks, the system hardly experienced any practical dissemination. On the one hand, building the silos requires a relatively high labour input. On the other hand, management of such storage demands a great deal of experience (LOZANO et al., 1978). What remains completely open is whether the storage duration of 4 weeks reached corresponds to the requirements of the farmers.

5.5.4 Storing fresh cassava roots in crates

Freshly harvested cassava roots can be stored in wooden crates. The crates are lined with a layer of sawdust. The spaces between the roots are also filled with sawdust. Finally, the roots are then covered with sawdust..

The sawdust, which can be replaced by any other resorbent material e.g. dust from coconut fibres, has to be damp but must not be wet. If the sawdust is too dry the roots will deteriorate quickly. Sawdust which is too moist promotes the formation of mould and rot. To prevent the roots drying out too early, the crate should be lined with plastic foil (RICKARD and COURSEY, 1981). A storage period of 4 - 8 weeks was attained with crates in experiments.

In Ghana this method of storage was modified and the crates were replaced by large baskets. The baskets were lined with fresh banana leaves which also served as a cover for the stored produce. Before storing the roots these were subjected to three days of curing. Storage periods in Ghana using this method reached 2 months (injured and cured roots) and up to 6 months (uninjured roots) (OSEI-OPARE, 1990).

The limited availability of crates and lack of suitable baskets which can only take up a small amount of roots in comparison to the value of products, have prevented this storage method from spreading. Both types of container are relatively expensive and the labour input involved in preparing the store and the produce is quite high.

However, this storage method could be interesting where fresh (sweet) cassava roots are sold over long distances. On the one hand, this method allows sufficient storage ability and distinctly reduces the risk of early deterioration. Secondly, the

crates or baskets can simultaneously be used as containers during transport (also several times) which saves on handling costs and also reduces injury to the roots during transport.

5.5.5 Storing fresh cassava roots in a dip

Storing fresh cassava roots in water is a widespread method on a household level and with traders in Ghana. For this, various sized containers are filled with water and the roots are completely submerged (OSEI-OPARE, 1990).

Storage duration can only be extended minimally by this method The roots stored in this way normally begin to ferment or spoil after 3 days. The effectiveness of this method depends greatly on the degree of freshness of the roots when they are stored (OSEI-OPARE, 1990). As the roots passed on to the dealers are mostly already 1 - 2 days old, the storage ability of the roots is hardly improved by this method

The limited extension of storage is not the sole criterion for the selection of this method of storage. This process is far more a method of simultaneously detoxifying the roots which contain hydrogen cyanide (cf. Chapter 5.6.2).

5.5.6 Storing fresh cassava roots in plastic bags

The use of plastic bags to preserve cassava roots can be seen as a consistent extension of traditional storage methods which serve the purpose of avoiding the loss of moisture and water stress (RICKARD and COURSEY, 1981).

Freshly harvested roots are put into bags. Fungicides should be applied before the

bags are closed to avoid the formation of mould and rot (BEST, 1990). When the roots which are packed airtight, breathe the oxygen content in the bags is reduced creating a preserving effect (RICKARD and COURSEY, 1981). High temperatures (above 40°C) as well as low temperatures (below 10°C) both have a positive effect on the duration of storage.

A storage duration of more than 14 days was reached in Columbia using this method (BEST, 1990). This method is particularly interesting for dealers and consumers. As with storing in crates, the risks involved in transport and sales is reduced for the trader. Consumers profit as the roots can be kept for a certain time after purchase. with the relevant infrastructure, this method of storage can provide new sales potential for production locations which are distant from the market.

One problem however, is that the consumer has to be convinced of the quality and the benefits (e.g. less frequent buying, storing to some extent in the home) of this "product innovation". The experience gained here in Columbia is quite positive (BEST, 1990). Direct transfer of this experience to conditions in Africa is however a problem as there are considerable differences between the living and eating habits. In addition, it must be determined whether the consumer is willing to bear the extra costs involved in storage.

5.5.7 Use of modern methods to store fresh cassava roots

The modern methods of storage involved here comprise refrigeration and freezing, waxing of the roots and chemical storage protection.

Reduced temperatures extend the storage ability of cassava roots by delaying the rot processes which occur rapidly at normal storage temperatures. Experiments have shown mat the most favourable temperature for the storage of fresh cassava roots is 3°C. Stored at this temperature, the total loss after 14 days amounted to 14% and after 4 weeks, 23% (RICKARD and COURSEY, 1981). A bluish mould occurs on the surface of the roots at higher storage temperatures and the flesh of the roots turns brownish. Both cause quality and storage losses (ibid.).

Cassava roots, or pieces of these, can be packed into plastic bags and frozen. Although the texture of the tissue becomes somewhat spongy the flavour is preserved (RICHARD and COURSEY, 1981). After defrosting, the roots remain edible for about 4 days. In some Latin American countries this method of preservation is used commercially. There are various preparations of freshly frozen cassava roots in shop refrigerators. These products are also entering supermarkets in European and American cities where a large number of African or Latin American inhabitants are potential customers.

Preliminary experiments towards preserving fresh cassava roots by coating them in wax were carried out in India. The wax contained a fungicide and the roots were dipped in it to coat them Storage duration could be extended to about 10 days with weight losses amounting to 10% (RICKARD and COURSEY, 1981). In Columbia fresh cassava roots were simply dipped in paraffin at a temperature of 90° - 95°C. Without any fungicide being used, the storage duration could be extended to 1 - 2 months (ibid.). Whether the storage ability is improved by the effect of the fungicide or whether this is due to the wax coating reducing respiration and the supply of oxygen has not finally been investigated.

The use of chemical agents to avoid mould and rot on foodstuffs is restricted for reasons of hygiene. The universal fungicide "Benomyl" was the only agent with which the formation of rot could be satisfactorily controlled for more man 10 days (RICKARD and COURSEY, 1981). This substance also had a reliable effect on treating the mould on roots stored in plastic bags.

Various commercial products tested had no effect on the discolouring of the vascular bundle. Only when this initial stage of deterioration can be controlled, will the control of the second phase of microbial root deterioration become interesting (RICKARD and COURSEY, 1981).

5.5.8 Measures to prepare fresh cassava roots for storage

For physiological reasons cassava roots are far less suitable for fresh storage than yam tubers. Despite this, the cassava roots have to be treated with just as much care as the yam tubers so that the maximum period of storage may be attained (cf. Chapter 3.7. 1).

It must be made sure mat the cassava roots are not injured or squashed during harvesting, transport and storage as injuries accelerate the physiological destruction of the tissue (blue coloration of the vascular bundle).

The most serious injuries occur at the shoulder of the root where it is connected to the plant by the root collar. This kind of injury can be avoided by harvesting the whole plant or by leaving a short piece of stalk on the root (INGRAM and HUMPHRIES, 1972). The roots harvested in this way discolour far more slowly than those harvested in a conventional fashion.

The deterioration of the roots can be delayed by cutting off the parts of the plant above the ground except for a short stalk stump. This should be done about 3 weeks prior to harvesting. The positive effect of cutting the above-ground parts of the plant off on storage ability is only retained when the roots are stored without any injuries (RICKARD and COURSEY, 1981).

5.5.9 Suitability of storage systems for fresh cassava roots on a small farmholder level

There are differences among farmers cultivating cassava, e.g. regarding the economical status of the crop, the resources for production input (work, capital and soil) and the market orientation and proximity. This makes the requirements of small farmholders regarding the storage of fresh cassava roots, very varied and not at all homogeneous.

The majority of West African small farmholders produce for the purpose of self-sufficiency with minimum resources. Cassava which is an undemanding plant in every respect, primarily serves the purpose of self-sufficiency and risk reduction. The proportion of production sold is generally very low.

The processes described above allow a very limited prolongation of storage. They mostly require an additional input of work and/or of capital which, in relation to the status of the cassava production, is relatively high. Some methods, i.e. cooling by means of external energy, constitute a technological leap and necessitate a functioning infrastructure.

For the majority of small farmholders, the methods described provide no solution

to their specific storage problems (long-term, secure, low losses and low-cost).

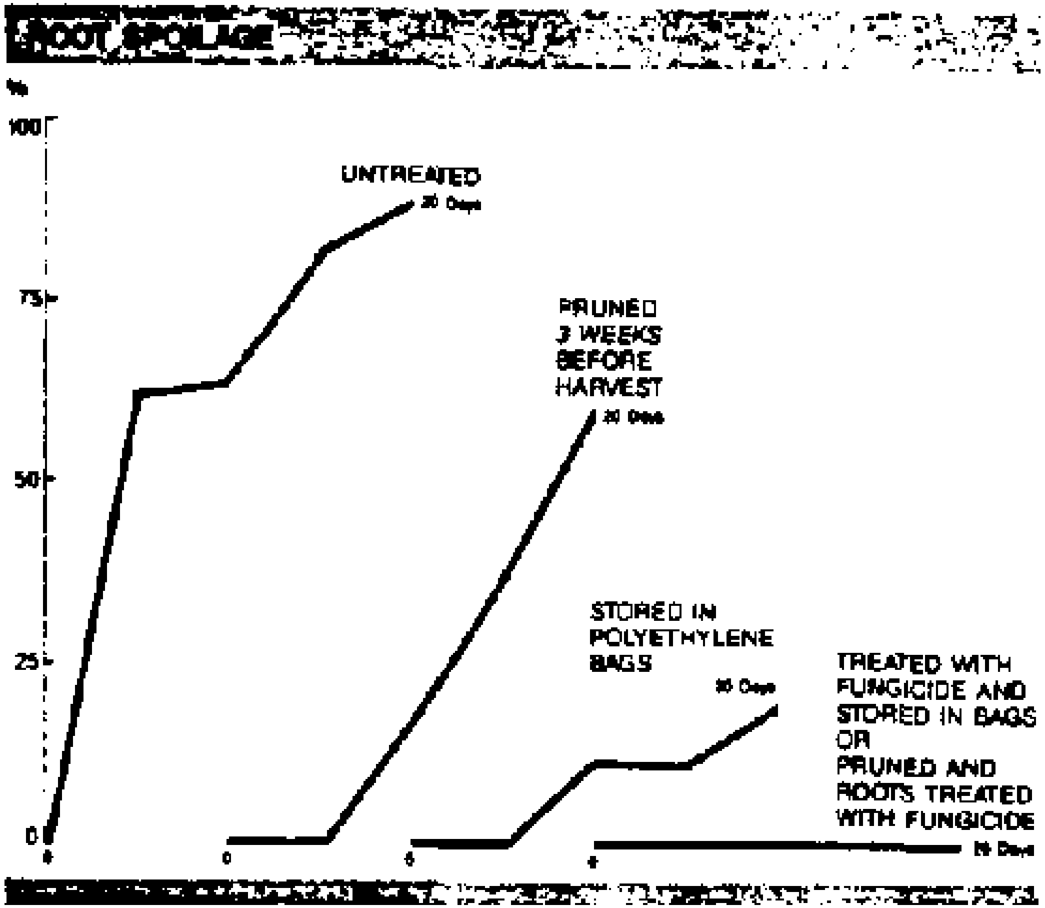


Fig 15 The effect of various measures on losses of freshly stored cassava roots with a storage period of 20 days (Source: COCK, 1985)

For farmers who have attained a certain integration into the market (fresh selling), individual methods are definitely of some interest. These can serve to bridge time gaps by minimally prolonging storage ability and by solving logistic problems by providing transport containers. The use of the methods described however, will only be successful if production and sales up to the final consumer

can be integrated into a system.

For the majority of farmers who produce cassava at some distance from the markets, other strategies become essential if their storage problems are to be solved. These strategies go in the direction of processing in order to produce products which can be stored. Some processes, e.g. the production of cassava chips as described below, can skill be included in the fields of storage and post-harvest technology. Other processes, e.g. the production of gari, are clearly a matter for foodstuff technology and are no longer a subject for this investigation.

5.6 The processing of cassava roots

5.6.1 The purpose of processing

As stated in the preceding chapters, the storage ability of fresh cassava roots is very limited in time This can only be prolonged slightly by the use of technical processes which, in some cases, are very costly (e.g. refrigeration). In view of this it is not surprising mat processes to conserve cassava roots have been developed.

There is a great variety of such processes ranging from simple drying through to processes which have to be considered as foodstuff technology (GRACE, 1977; COCK, 1985). Traditional methods of processing which are typical for some regions, e.g. the production of gari in West Africa, have been completely mechanised during the course of time. This has contributed to relieving particularly women of work (NZOLA-MESO and HAHN, 1982).

The main purpose of processing cassava roots is to get a product which will keep and which can be stored. Numerous production processes achieve this by drying

the cassava roots. A welcome side-effect of drying is the concentration of the contents which determine its value. The ability of the product to be transported is considerably improved.

In addition to conserving, processing also detoxifies the cassava. This is necessary since the bitter varieties of cassava in particular have very high concentrations of hydrogen cyanide which can lead to serious health hazards.

5.6.2 Hydrogen cyanide and its release

Cassava roots contain hydrogen cyanide (HCN) which is a very strong poison. The lethal dose for an adult is approx. 60 mg per day (HAHN, 1989). Due to the high content of HCN, an unbalanced diet containing only fresh cassava products can lead to poisoning, deficiency and deformity. These occur especially if cassava roots have not been sufficiently detoxified and if there is a protein deficiency in particular of amino acids containing sulphur. The latter promote a very effective natural body detoxification process (HAHN, 1989).

The concentrations of hydrogen cyanide in the cassava roots depend on the variety. The content can amount to only a few milligrams but also to over 300 mg per kilogram of fresh root (HAHN, 1989). HCN is also unevenly distributed within the root. There are high concentrations in the outer cell layers and in the upper part of the root (HAHN, 1989). The bitter flavour cassava roots have does not indicate the content of HCN (LANCASTER and COURSEY, 1984).

Hydrogen cyanide does not occur freely in the cassava root but is combined with linamarin and lotaustralin, two cyanoglycosides. HCN is released by means of a

hydrolytic process which is activated by the enzyme linamarase (COURSEY, 1982). Hydrolysis always takes place when the enzyme comes into contact with the cyanoglycoside. The natural release of hydrogen cyanide is encouraged by the mechanical destruction of the tissue or the disintegration of the cellular structures due to storage (LANCASTER and COURSEY, 1984).

Drying, boiling, immersing in water over a longer period and fermenting also encourage the release of HCN. What is promoted here is less hydrolysis and more the release of HCN which has already been detached due to the activity of the enzymes with the glycoside.

Even when the cassava roots are properly processed a residue of hydrogen cyanide remains. The concentrations however are mostly so minute that no hazard to health will occur from eating them (HAHN, 1989).

5.6.3 The production of cassava chips

The production of cassava chips is the most simple way of obtaining a product, on the basis of cassava, which will keep and which can be stored. Cassava chips are for the purpose of self-sufficiency, as e.g. in West Africa (STABRAWA, 1991) as well as for obtaining income and foreign currency. The latter applies particularly to Thailand (COCK, 1985).

The production process always follows the same pattern and more or less shows a high degree of mechanization. Slight deviations from this lead to chips with varying quality features reflecting the regional demand and flavour preferences. The possible variations on the standard processes here, will be dispensed with at

this point. Firstly, these are far too numerous, often-only of regional importance, and secondly, documentation on this is rare.

Chips are not only made from cassava but can also be produced from yams. Due to the lower content of dry matter in yams in comparison to cassava correspondingly more energy has to be used to dry them. Seen from the volume of production, cassava chips are far more significant than yam chips. As the production processes for both products are virtually identical the method of producing yam chips is not to be discussed at this point.

5.6.3.1 Preparation of the cassava roots for the production of chips

The cassava roots are peeled immediately after harvesting with the traditional cutting tools, e.g. brushwood knife (machete). The peeling, mainly carried out manually by women, requires a great deal of work. One woman can peel about 20 -25 kg roots in one hour (SADIK, 1987). The loss in weight occurring due to peeling amounts to about 30% of the fresh weight (ibid.).

Various peeling machines have been developed in West Africa. These have not been widely accepted because the purchase prices are too high and the machines cause too great a loss in peeling (ibid.).

The roots peeled are men washed. If the chips are obtained from bitter cassava varieties, the roots frequently are kept in water after peeling. This causes hydrogen cyanide to be released, reducing the danger of poisoning (JAKUBCZYK, 1982). For a sufficient release of hydrogen cyanide, the roots should be soaked for 2 - 4 days (JOSEPH, undated). A good release of hydrogen cyanide is attained if

the roots are cut into pieces prior to soaking. These are men soaked in water for 15 minutes and then boiled for 2 minutes (JAKUBCZYK, 1982).

Another method of preparation is to briefly boil the freshly peeled roots in water. Then they are halved lengthwise and soaked in water for 1 - 2 days. The water should be changed once to twice during this time (ONWUEME, 1978).

Which process is preferred, particularly regarding the release of hydrogen cyanide, has not yet been sufficiently investigated.

The cassava roots prepared in this way are cut into pieces for drying. How the roots are split up and how large the pieces are, vary from region to region and depend on the relevant eating. The size of the pieces of root is also influenced by climatic drying conditions. Thus the pieces are mostly larger in the dry northern parts of Ghana man those in the south of the country (KWAKU, 1991).

In some cases the cutting of the roots has also been mechanised. The machines used for this chip the roots into small pieces which dry correspondingly well (COCK, 1985).

5.6.3.2 Drying the cassava chips

To store well, the chips have to be dried to a moisture content of about 12% (COCK, 1985). Completely dried chips are white and break easily without crumbling (INGRAM and HAMPHRIES, 1972). Drying is frequently inadequate when the chips are to be sold directly after they have been dried (INGRAM and HAMPHRIES, 1972). Pricing which is oriented to the weight of the product, can be manipulated in favour of the seller by increased moisture content.

The prepared chips are spread out on all sorts of supports to dry. They are laid out on the roofs of houses, the edges of roads or in yards. No special constructions developed for chip drying are known of in West Africa. Chips laid out to dry are often soiled by rain, sand and animal excrement which leads to losses in quality due to hygiene (JAKUBCZYK, 1982).

The energy from the sun and wind are mainly used to dry the chips. High energy costs normally make the use of external energy (wood and fossil fuels) to dry the chips unviable. The drying process however, is often supported by wood fires and the use of heat from stoves (CHINSMAN and FIAGAN, 1987). The smoke emitted is said to act as an insecticide. But smoke also leads to discolouring and changes in the flavour of the chips which is not always desired.

The duration of drying depends on the size of the chips and on climatic conditions. Under optimum conditions. the chips can be completely dried within 2 days by using the energy from the sun and the wind (COCK 1985)However the drying period is mostly much longer and frequently takes between two and three weeks (INGRAM and HAMPHRIES, 1972).

During the long drying period the chips often become mouldy and ferment. This makes the originally white chips discoloured and also changes their flavour. The Ada, an ethnic group native to Ghana, want this qualitative change to take place during drying (NICOL 1991). In the opinion of the Ada, the fungus settling on the chips is evidence of a low content of hydrogen cyanide. Consequently, they believe that chips infested by mould are quite suitable for human consumption (ibid.). Mould as an indicator for the non-toxicity of chips has not yet been proven scientifically.

Chips are often briefly boiled in water (parboiled) after drying and men dried again. This makes the chips harder and is to improve their storage ability and reduce their susceptibility to infestation by pests. Investigation however show varying results (STABRAWA, 1991;INGRAM and HUMPHRIES, 1972).

5.6.3.3 The storage of cassava chips

The demands cassava chips have on storage conditions are similar to those of cereals (COURSEY, 1982). Cassava chips are hygroscopic and tend to draw moisture which promotes the formation of mould and thus early deterioration.

Many stored product insects which cause damage to cereals also infest cassava chips (cf. Chapter 5.6.3.4). Consequently, storage structures should on the one hand provide some protection from reabsorbing moisture, but should also avoid infestation by pest insects. This must be qualified by saying that cassava chips are often infested by pest insects during the drying process. For this reason, as already mentioned in Chapter 5.6.3.2, the drying process is of particular importance in the storage of chips.

In contrast to the yam tubers for which specific storage systems have been developed, cassava chips are kept in stores which are also used to store cereals and grain legumes (STABRAWA, 1991). Thus, cassava chips are stored in baskets, in wooden containers, in sacks or in bulk in storage rooms as well as in various traditional storage systems intended for cereals (INGRAM and HAMPHRIES, 1991). Frequently varying storage systems are used side by side which can serve to fulfill the varying storage requirements (STABRAWA, 1991).

Of great importance in the selection of certain storage systems are the availability of various building materials, the existence of certain artisanal knowledge, capital and labour. In contrast, cultural customs and traditions play only a minor role (COMPTON, 1991). In many areas, there are however skill close associations between the structural features of storage systems and certain ethnic groups. These are normally a result of artisanal traditions and experience being passed down within certain groups. This experience is also freely passed on to members of other groups and used by these ('bid.), indicating some openness regarding technical storage innovations.

In Togo, there are three traditional types of storage in particular which are preferred for storing cereals but also for cassava chips.

Fig 16: "Kpeou", a traditional storage system for cassava chips (Source: LAMBONI, undated)

The "kpeou" is a storage structure which consists of mud or often of the material

from termite mounds. It is shaped like a water jug and is often divided into several chambers (Fig. 16). The store often reaches a height of over 2 metres. The upper edge of the "kpeou" has an opening for filling and entering which can be firmly closed. The "kpeou" is relatively expensive to erect but has a service life of 20 - 30 years. In Togo the "kpeou" is the only closed storage system. As there is no method of ventilation due to the way of building, the produce which is to be stored must be dried optimally (chips should not have a moisture content greater than 12%).

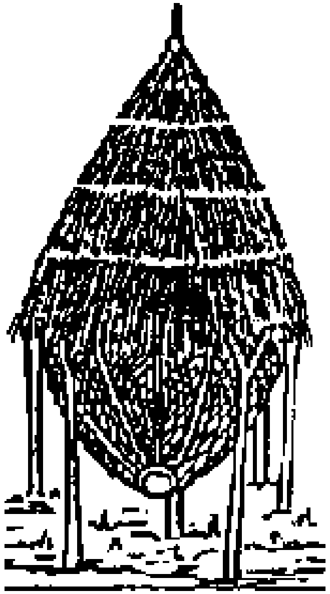


Fig. 17: "Katchalla", a traditional storage system for cassava chips (Source: LAMBONI, undated)

The "katchalla" is made of wood and straw. It looks like a cone which is upside down and is stabilized by wooden supports (Fig. 17). The "katchalla" has an opening at the peak of the cone which is closed by a conical roof. The storage system is not airtight, but has some ventilation.

The "tonneau" can be compared to a large barrel and is erected on a low platform. The "tonneau" consists of a wooden frame in which mats are stretched. The "tonneau" is open at the upper edge and is closed by a conical roof (Fig. 18). It is often constructed to a height of more than 2 meters. This system is also open and allows air exchange between the stored produce and the atmosphere.

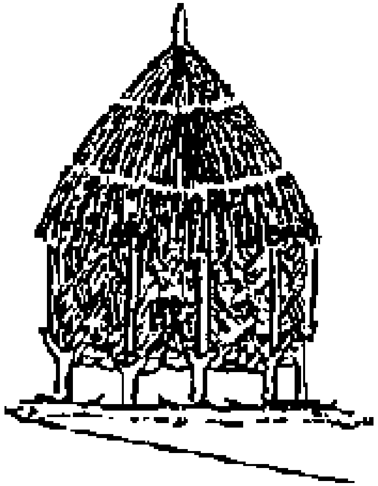


Fig 18: "Tonneau", a traditional storage system for cassava chips (Source: LAMBONI, undated)

According to the studies by COMPTON (1991) and STABRAWA (1991), about 60% of cassava chips are stored in traditional storage systems (34% "kpeou" and 26% "katchalla) in the central region of Togo. The remaining 40% are kept in varying types of storage of which storage in sacks and as bulk produce in storage rooms are the most significant.

The average storage duration for cassava chips amounts to 7 months, but can extend to over one year (STABRAWA, 1991). Other sources state a storage duration of 3 - 6 months for sun-dried and of up to 12 months for "parboiled"

cassava chips before serious mould begins (INGRAM and HAMPHRIES, 1972).

The duration of storage is influenced by a large number of factors which can vary greatly from region to region. In addition to natural influences, the duration of storage is also affected by socio-economic factors. In Togo, for example, the chips which are intended for sale are stored for 7 - 8 months in order to take advantage of price fluctuations due to quantities in supply. Chips serving self-sufficiency purposes are stored up to a period of 12 months, i.e. until the new harvest is brought in (STABRAWA, 1991).

5.6.3.4 Losses in storage due to pest insects

Stored product insects cause high losses in the storage of cassava chips. These pests infest not only cassava chips but also other foods which are stored under tropical conditions (HODGES et al., 1985). According to LAMBONI (undated), Prostephanus truncatus (Horn), Dinoderus minutus and Tribolium sp. are among the most significant pest insects in the storage of cassava chips among small farmholders in Togo.

Prostephanus truncatus (Horn) which did not appear as a pest in Togo until the beginning of the eighties, can be easily confused with Dinoderus which also causes damage to stores of cassava chips (STABRAWA, 1991). The losses caused by Prostephanus truncatus (Horn) can be very high. HODGES et al. (1985) determined weight losses of up to 50% for unfermented and up to 70% for fermented chips after a storage period of 4 months which were ascribed to this storage pest.

The differences in the amounts of loss are caused by the varying density of the two types of chips. Unfermented chips are denser making it more difficult for the grain borer to penetrate them man fermented chips. The production of unfermented chips cannot be recommended as protection from infestation by Prostephanus as these are also subject to serious infestation (HODGES et al., 1985).

To quantify the storage losses for cassava chips which are caused by insects is very difficult as firstly, suitable methods for an estimation of the losses do not exist. The NRI has been endeavouring to find a basis for a solution to this for some time now. Secondly, the farmers evaluate the losses of cassava chips due to insects in a different way than for e.g. maize. The badly damaged chips and the flour from boring are mostly still used for human consumption, the insects being sieved out beforehand (STABRAWA, 1991). The farmers consider the worse plasticity of the cassava paste made from this to be a considerable disadvantage of this insect infestation in comparison to that made out of uninfested chips (COMPTON, 1991). Since only a third of the paste mixture consists of cassava chip flour, the negative effect of the insect on the consistency of the paste is limited (ibid.).

Insects often infest the chips during drying (cf. Chapter 5.6.3.2). They can also not infest the stored produce until it is put in storage. Since farmers consider the losses caused by the insects only as partial losses, practically no traditional preventive measures have been developed. In particularly the high losses caused by Prostephanus truncatus (Horn) have led to isolated farmers making use of chemical products for storage protection (COMPTON, 1991). The selection of insecticides is made at random and depends only on market supply. So far, the

effect of these products and the formation of possible residues which could constitute a health hazard have not been investigated. For this reason, no insecticides, dosages or application methods can be recommended here.

5.6.3.5 Storage losses due to mould

Mould frequently infests the cassava chips during the drying stage. However, mould also forms if the chips again become moist in storage (INGRAM and HUMPHRIES, 1972). Not only one variety of fungus but several occur on the chips simultaneously. It teas not yet finally been determined which metabolites form the various varieties of fungus, or whether mycotoxins are possibly among these.

The formation of mould cannot be basically seen as a loss in quality or a cause of loss. Some ethnic groups appreciate infestation of the chips by mould and even speak of improvements in the flavour here (cf. Chapter 5.6.3.2). In Burundi, a Belgian company attempted to improve the nourishing qualities of cassava chips by directed mould infestation (JOSEPH, 1986). Disregarding the regionally varying preferences for particular flavouring, mould on chips mostly leads to distinct losses in value. This applies particularly if the chips are intended for sale. For these reasons the only recommendation at this time can be to avoid the formation of mould on chips during production.

5.6.3.6 Measures to improve the production and storage of cassava chips

The storage ability of cassava chips is strongly influenced by the drying process. Drying which takes too long, promotes insect infestation leading to extensive storage losses. If the chips are only insufficiently dried and still have mote than

12% moisture content, the danger of mould will exist. Mould also forms when the hydroscopic chips are not sufficiently protected from the moisture in the atmosphere and re-absorb moisture during storage.

Improvements to the production and storage of cassava chips have thus to begin at the drying stage. At the same time, a storage has to be practiced which not only has to provide protection from the penetration of insects, but also against re-moisturising of the stored products.

Peeling the cassava roots requires a great deal of labour. The mechanisation processes devised so far are more for peeling large quantities (e.g. for gari production) man for use on small farms. A technology which saves labour and hardly causes any extra costs, which substantially improves the labour productivity of peeling and thus seems predestined for introduction to the a.m. target group is the peeling knife developed by the IITA. In Togo at least, this knife is not widespread and should thus be put to practical tests as a measure of improving the labour productivity. A direct contribution to relieving the woman of labour could be made here since the peeling of the roots is her responsibility.

The drying process can be shortened by increasing the surface area of the chips in relation to their volume. The larger chips which are often spread out to dry in many regions of Africa have to be reduced in size to improve their drying properties. The principle to be followed here is: the smaller the chips, the faster drying takes place.

Before measures can be recommended, the reasons for the size of the chips must be investigated. If mere are reasons for this which stem from work management,

it must be investigated whether a technology can be introduced to increase labour productivity. In this respect, the microeconomic viability has to be analysed just as the acceptance of the procedure by the population concerned. Examples of mechanisation for chip production using slicers can be seen in work by COCK (1985) amongst others.

In the past, only the rays of the sun were normally used for drying the chips. These are extensively reflected by the white chips and are partly lost for the drying process. As experiments have shown, drying can be substantially improved if wind energy is also used in addition to the energy from the sun (COURSEY, 1982).

For this purpose the chips are laid out to dry on a wooden frame covered with wire mesh. The frame can be any size but should be chosen so mat it can be easily handled. This is the case when it is has an approximate size of 1.5 x 1 m. The wire used to stretch over the frame should be fine enough to prevent the chips falling through the mesh. This wire can be substituted by any locally available materials which can be permeated by air.

The wooden frames are set up at a definite angle so that the rays of the sun fall on the chips and so that the natural movement of the wind constantly aerates these (cf. Fig. 19). In this way, cassava chips can be optimally dried within 2 days (COCK, 1985).

In addition to this mobile frames offer further advantages. If unexpected rain showers occur, they can be cleared away with the chips which prevents with during the drying process and thus a reduction in quality. There are also hygienic

benefits of using the frames since the chips no longer come into contact with the dirt from the streets or the yard as is usual in traditional drying processes.

Storage structures where chips are traditionally stored do not always provide sufficient protection from pest insects or with Of the traditional storage structures used in Togo, the "kpeou" (cf. 5.6.3.3) seems to be suitable for the storage of cassava chips. However, the storing features of this structure must be investigated in more detail. Apart from this traditional system, other containers can be used to store cassava chips under some circumstances. Literature mentions e.g. plastic sacks. Plastic barrels and used oil barrels also seem suitable for storing cassava chips. The storage properties of these must be initially investigated before any recommendation for storage in these containers can be made.

There are no proven results on processes of chemical storage protection for cassava chips. From Togo, it is known, and this definitely also applies to other countries as well, mat the farmers use chemical insecticides for cassava chips at random when pest infestation occurs. Since considerable health hazards can occur when treated chips are consumed, investigations should be carried out to define recommendations on products and on application which will men allow storage protection without any risk to health

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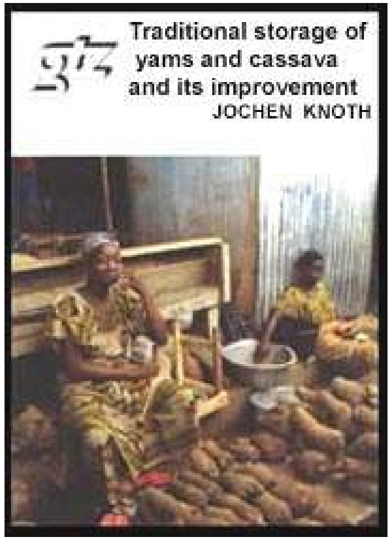
Traditional Storage of Yams and Cassave and its



Improvement (GTZ)

6 Summary

As carriers of carbohydrates, tropical roots and tubers contribute greatly to securing the basic nutrition. This particularly applies to the countries of the humid tropics in Africa where this group of products often secures over 50% of the nutrients for local populations.

Judged by the area on which they are cultivated and the total yield, cassava and yams are the most significant roots and tubers in Africa. Therefore this work concentrates on these two crops.

Tropical roots and tubers have a high output per unit area and, with the exception of yams, have low demands on soil quality. They are marked by high resistance to

drought and low susceptibility to mass pests.

These properties are the reason why roots and tubers have a firm place in small farm systems. Here, they contribute to reducing the risks involved in cultivation and frequently serve the purpose of providing nutrition during bottlenecks.

In contrast to specific advantages in production, roots and tubers have negative storage properties mainly resulting from the high water content of their storage organs. High losses are consequently a feature of their post-harvest behavioural pattern.

The bad storage properties have thus contributed to traditional societies searching more for measures to avoid storage than for measures to improve this. To avoid storage in a fresh state, the roots and tubers are frequently processed into dry products which will keep.

Traditional storage systems for fresh products have been developed for yams in particular whose tubers have a natural storage quality due to their dormancy. These systems are all very simple in design 'end have often remained unchanged over a long period.

Improvements to traditional storage systems for fresh yam tubers are possible. These must begin at the time of harvesting when tubers should be handled carefully so that uninjured tubers can be put into storage. Small technical improvements to keep away pests, to improve the climate in storage and to facilitate regular control of the stored produce can contribute substantially to reducing losses.

The lack of storage ability of fresh cassava roots is caused mainly by physiological processes leading to fast destruction of the root tissue. All experiments to substantially prolong the storage of fresh cassava roots so far have not been convincing.

The only possibility of storing fresh cassava roots consists of leaving them in the ground after the harvest. In this way, the roots can be "stored" for several months without showing any great losses. However, this blocks land for the cultivation of other crops.

The most simple method of overcoming the lack of storage ability in fresh cassava roots is to produce dried chips. This is a traditional process and is widespread in Africa. The storage of cassava chips can be improved particularly by reducing the process of drying which frequently takes several weeks. This can take place by preparing smaller chips and by making use of the energy from the wind and the sun for drying.

Storage of the dried chips with a remaining moisture content of 12% should be in insect-proof containers. The definition of suitable storage systems, of both traditional and modem design, and the measures of chemical storage protection, both require more detailed examination before recommendations can be made on applying these to cassava chips.

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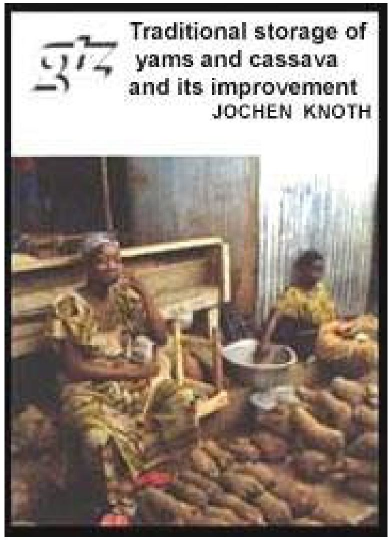

Traditional Storage of Yams and Cassave and its Improvement (GTZ)

7 Bibliography

AFRICAN REGIO. CENTRE FOR TECHNOLOGY (ARCT) (edi.) (1982).
Roots and Tubers Production, Storage, Processing and Marketing in Africa, Dakar.

ASIEDU, J.J. (1986).
Processing and Physical/Chemical Properties of Tropical Products Pfaffenhofen.

BAUTISTA, O.K. (1990).
Postharvest Technology for Southeast Asian Perishable Crops, Los Banos.

BAYBAY, D.S. (1981).

Storage of Some Root Crops and other Perishable Farm Products, in: Philippine Agriculture, vol.10, n° 9, pp 423-440.

BEEN, B.O. et al. (1977).
Yam Curing for Storage, in: Acta Horticulturae, vol. 62, pp 311-316.

BEST, R. (1979).
Cassava Drying, Cassava Information Centre, CIAT, Cali/Colombia.

BEST, R. (1990).
Storage and Processing of Cassava in Latin America, Lessons for the Subregion (West Africa), m: FOOD AND AGRICULTURE ORGANIZATION (FAO) (1990b). Action Programme for the Prevention of Food Losses, Improving Post-Harvest Handling, Storage and Processing of Root and Tuber Crops, Rome, pp 9-20.

BOOTH, R.H. (1978).
Storage. In Pest Control in Tropical Root Crops, in: Pest Articles and News Summaries, n° 4, pp 37-43.

BOOTH, R.H. (1976).
Storage of Fresh Cassava Manihot esculenta) I. Post-Harvest Deterioration and its Control, in: Experimental Agriculture, vol. 12, pp 103-111.

CENTRE FOR OVERSEAS PEST RESEARCH (1978).
Pest Control in Tropical Root Crops, Pans Manual n°4, London.

CHAN, H.T (Jr.) (edi.) (1983).
Handbook of Tropical Foods, New York.

COCK, J.H. (1985).
Cassava, New Potential for a Neglected Crop, London.

COMPTON, J. A. F. (1991).
Survey of Farm Storage of Maize and Dried Cassava, Central Region, Togo.

COURSEY, D.G. (1961).
The Magnitude and Origins of Storage Losses in Nigeria Yams, in: Journal of Science Food and Agriculture, n° 12, pp 574-580.

COURSEY, D.G. (1966).
Food Technology and the Yam in West Africa, m: Tropical Science vol. 3, n° 4, pp 1-52-159.

COURSEY, D.G. (1967).
Yams, London.

COURSEY, D.G. (1967).
Yam Storage - 1.: A Review of Yam Storage Practices and of Information on Storage Losses, in: Journal of Stored Products Research, vol. 2, pp 229-244.

COURSEY, D.G. (1981).
The Interaction from Yam and Man, in : Journal d'Agriculture Traditionnelle et de Botanique Appliques, vol. 28, n° 1, pp 5-21.

COURSEY, D.G. (1982).
Tropical Root Crop Work at the Tropical Products Institute, m: African Regional Centre for Technology (ARCT) (edi.): Roots and Tubers Production, Storage,

Processing and Marketing in Africa, Dakar, pp 141-168.

COURSEY, D G. (1983).
Yams, in: CHAN H.T. (Jr.) (edi.) (1983), Handbook of Tropical Foods, New York.

COURSEY, D.G. and WALTER H.M.(1960).
A Study of the Origins of Weight Losses m Stored Yams, in: Report of West African Stored Products Research Unit, pp 61-64.

DEMEAUX, M. and VIVIER, P. (1984).
Mthodes modernes de conservation des ignames in: L'Agronomie Tropicale, vol. 39, n° 2, pp 184-191.

DEUTSCHE STIFTUNG FR INTERN. ENTWICKLUNG (DSE) (edi.) (1989).
Roots, Tubers and Legumes, Bonn.

FOOD AND AGRICULTURE ORGANIZATION (FAO) (1981).
Food Loss Prevention in Perishable Crops, FAO, Agricultural Services Bulletin n° 43, Rome.

FOOD AND AGRICULTURE ORGANIZATION (FAO) (1986).
Role of Roots, Tubers and Plantains in Food Security in Sub-Sahara Africa. Report to the Committee on World Food Security, 11me Session, 9 au 16 avril 1986, Rome.

FOOD AND AGRICULTURE ORGANIZATION (FAO) (1990).
Prograrnme d'action pour la prvention des pertes de produits alimentaires, rapport d'activits sur l'amlioration du stockage des ignames en milieu paysan,

Lom.

FOOD AND AGRICULTURE ORGANIZATION (FAO) (1990b).
Action Programme for the Prevention of Food Losses, Improving Post-Harvest Handling, Storage and Processing of Root and Tuber Crops, Rome.

FOOD AND AGRICULTURE ORGANIZATION (FAO) (1985).
Production Year Book, vol. 38, Rome.

GESELLSCHAFT FR AGRARPROJEKTE (GFA) 1985).
Frderung der Yamsproduktion in der Zentralregion - Togo, Hamburg.

GESELLSCHAFT FR AGRARPROJEKTE (GFA) (edi) (1991).
Prospektion zur Prfung neuer Arbeitsbereiche fr das GTZ-Projekt fr Nacherntefragen in Benin, Ghana und Togo, Tomes I III, Hamburg.

GRACE, M.R. (1977).
Cassava Processing, FAO Plant Production and Protection Series n° 3, Rome.

HAHN, N.D. (1989).
The African Farmer and Her Husband, m: DEUTSCHE STIFTUNG FR INTERNATIONALE ENTWICKLUNG (DSE) (edi.): Roots Tubers and Legumes, Report of the Expert Meeting, Bonn, pp 71 -93.

HAHN, S.K. et al. (1987).
Cassava and the African Food Crisis, in: TERRY, E.R. (edi.) (1987). Tropical Root Crops, Root Crops and the African Food Crisis, Nigeria.

HODGES, R.T et al. (1985)
Infestation of Dried Cassava (Manihot Esculenta crantz) by Prostephanus Truncatus (Horn) (Coleoptera: Bostrichidae), in: Journal of Stored Products Research, vol. 21, n 2, pp 73-77.

INGRAM, J.S. and HUMPHRIES, J.R.O. (1972).
Cassava Storage - a Review, in: Tropical Science, vol. 14, n° 2, pp

INSTITUT DES PLANTES A TUBERCULES (INPT) (1988).
L'igname: Techniques de production et de conservation, Lom.

JABUBCZYK, T.E. (1982).
Roots and Tubers Processing in Some African Countries, in: AFRICAN REGIONAL CENTRE FOR TECHNOLOGY (ARCT) (edi.) (1982). Roots and Tubers Production, Storage, Processing and Marketing in Africa Dakar, pp 112-126.

JOSEPH, S.M. (1986).
Etude de prfactibilit de projets sur la conservation, le schage, I'emballage et la commercialisation des tubercules dans les pays membres de la CEPGL et du MULPOC de Gisenyi, Partie C: Cas du Burundi, Bujumbura.

LAMBONI, B.(undated).
Rapport de mission d'tude sur les cossettes de manioc dans les rgions de la Kara et Centrale, Lom.

LANCASTER, P.A. and COURSEY, D.G. (1984).
Traditional Post-Harvest Technology of Perishable Tropical Staples FAO (edi.), Agricultural Services Bulletin 59, Rome.

LEIHNER, D. E. (1991)
Der Beitrag tropischer Wurzel- und Knollenfrchte fr buerliche Familienbetriebe und nationale Volkswirtschaften, in: Entwicklung und Lndlicher Raum, Jg. 25, H. 1, pp 3-7.

LOZANO, J. C. (1978).
New Developments in Cassava Storage. Proceedings of Cassava Protection Workshop, CIAT, Cali/Columbia.

LYNAM, J. K. (1991).
The Development Potential of Root Crops in Africa in: Entwicklung und Lndlicher Raum, Jg. 25, H. 1, pp 8-12.

MARTIN, F. W. (1977).
Prolonging the Storage Life of Yams by Removal of Shoots and by Treatment with Gibberellic Acid and Waxes, in: Tropical Root and Tuber Crop Newsletter, Vol 10, pp 39-44.

MIEGE, J. and LYOND, S. N. (edi.) (1978).
Yams/Ignames, Proceedings IFS. Symposium.

NICOL, K. (1991)
Post-Harvest Protection of Root and Tuber Crops for Small Farmholders, in GESELLSCHAFT FUR AGRARPROJEKTE (GFA) (edi) (1991), Prospektion zur Prfung neuer Arbeitsbereiche fr das GTZ-Projekt fr Nacherntefragen in Benin, Ghana und Togo, Bericht der lokalen Gutachter, (Bd. 2, Ghana), Hamburg, pp 1-26.

NIGERIAN STORED PRODUCTS RESEARCH INSTITUTE (1982).

Storing Your Produce, Advisory Booklet No. 2, Yam Tubers & Dried Yam, Lagos.

NNODU, E.C. (1986).
Pit-curing Technique for Prolonging the Shelf Life of Yam Tubers, in: TERRY, E.R. (edi.), Tropical Root Crops, Root Crops and the African Food Crisis, Nigeria, pp 140-142.

NWANKITI, A. D. O. et al. (1989).
Traditional and Some Improved Storage Methods for Root and Tuber Crops in Nigeria in: DEUTSCHE STIFTUNG FR INTERNATIONALE ENTWICKLUNG (DSE) (edi.): Roots, Tubers and Legumes, Bonn, pp 51 -67.

NWANKITI, A. O. et al. (1988).
Effects of modifying Two Traditional Yam Barn Structures on Storability of Four Cultivars of Yam (Dioscorea spp.), in: Tropical Agriculture (Trinidad) Vol. 65, No. 2, pp 125-128.

NZOLA-MESO, M. and HAHN S.K. (1982)..
Production and Transformation of Cassava in Africa, in: AFRICAN REGIONAL CENTRE FOR TECHNOLOGY (ARCT) (edi.) (1982). Roots and Tubers Production, Storage, Processing and Marketing in Africa Dakar, pp 127-140.

OKIGBO, B. N. (1986).
Keynote Address: Roots and Tubers in the African Food Crisis, in: TERRY, E.R. (edi.). Tropical Root Crops, Root Crops and the African Food Crisis, Nigeria, pp 9-20.

ONAYEMI, O. (1982),

Roots and Tubers in Africa - Their Economic Importance and Technological Problems in: AFRICAN REGIONAL CENTRE FOR TECHNOLOGY (ARCT) (edi.), Roots and Tubers Production Storage, Processing and Marketing in Africa Dakar, pp 1-14.

ONWUEME, I. C. (1978).
The Tropical Tuber Crops, Chichester.

OSEI-OPARE, A. F. (1990).
Household and Village Level Storage and Processing of Root an Tuber Crops in Ghana Lessons for the Sub-Region-West-Africa in: FOOD AND AGRICULTURE ORGANIZATION (FAO) (1990b). Action Programme for the Prevention of Food Losses Improving Post-Harvest Handling, Storage and Processing of Root and Tuber Crops, Rome, pp 46-57.

OSIRU, D. S. O. et al. (1992)
Advances in Yam Storage, in: Tropical Root and Tuber Crops Bulletin Vol. 6, No. 1, p 7.

PASSAM, H. C. (1977).
Sprouting and Apical Dominance of Yam Tubers, in: Tropical Science Vol. 19, No. 1, pp 29-39.

PASSAM, H. C. (1978).
Dormancy of Yams in Relation to Storage, in: MIEGE, J. LYOND, S. N. (edi.): Yams/Ignames, Proceedings IFS. Symposium, pp 285-293.

PASSAM, H. C. and IRELAND C. R. (1985).

Effects of Exogenous Batatasin, Batatasin Analogues and Gibberellins on the Dormancv of Stored Yam Tubers, in: Tropiccal Agriculture (Trinidad), Vol. 62, No. I, pp 41-46.

PASSAM, H. C. and NOON, R. A. (1977).
Deterioration of Yams and Cassava during Storage, in: Annals of Applied Biologiy, Vol. 85, pp 436-440.

PAULINO, L. A. and YEUNG, P. (1981).
The Food Situation in Sub-Sahara Africa: A Preliminary Assessment, Washington DC.

PERLASCA, G. (1956).
Chemical Control of Sprouting in White Potatoes, in: American Potato Journal, Vol. 33, pp 11-3-133.

PLUMBLEY, R. A. (1982).
Improvement of Storage of Root Crops, Umudike/Nigeria.

PLUMBLEY, R. and RICKARD, J. E. (1991).
Post-Harvest Deterioration of Cassava, in: Tropical Science, Vol. 31 pp 295-303.

RICKARD, J. E. and COURSEY D. G. (1981).
Cassava Storage, Part 1: Storage of Fresh Cassava Roots, in: Tropical Science, Vol. 23, No. 1, p 32.

SADIK, S. (1987).
Role of Post-Harvest Technology of Root and Tuber Crops, Plantains and Bananas

in West-Africa, Rome.

SAUPHANOR B. and RATNADASS, A. (1985).
Problmes entomologiques la conservation de l'igname en Cte d'Ivoire, in: L'Agronomie Tropicale, Vol. 40, No. 3, pp 2-61-270.

STABRAWA, A. (1991).
Study of the Maize and Cassava Faarming and Storage Systems in Central Togo with Reference to the Impact of the Larger Grain Borer (Draft Report), Natural Recource Institute (NRI), Kent.

TERRY, E. R. (edi.) (1987).
Tropical Root Crops, Root Crops and the African Food Crisis, Nigeria.

VEELBEHR, E. (1991).
Traditionelle Nahrunesmittel in Afrika: Stiefkind der Entwicklungspolitik? in: Entwicklung und Lndlicher Raum, Jg. 25, H. 1,p2.

WICKHAM, L. D. et al. (1984a).
Tuber Development Storage and Germination in Yams (Dioscorea ssp.) in Response to Pre-Harvest Application of Plant Growth Regulators, in: Journal of Agricultural Science, Vol. 102, pp 437-442.

WICKHAM, L.D. et al. (1984b).
Dormancy Response to Post-Harvest Application of Growth Regulators in Dioscorea Species, in: Journal of Agricultural Science, Vol. 102, pp 427-432.

WILSON, J. (undated).

Careful Storage of Yams Commonwealth Secretariat, International Institute of Tropical Agriculture, Ibadan.