QUANTITATIVE ASSESSMENT OF

STORAGE LOSSES

IN

ROOTS AND TUBERS.

(A CASE STUDY OF NIGER STATE).

BY

EJELE DANIEL OHIEMIEME

(90 / 1485)

DEPARTMENT OF AGRICULTURAL ENGINEERING,

SCHOOL OF ENGINEERING AND ENGINEERING TECHNOLOGY

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

NIGER STATE.

CERTIFICATION.

This is to certify that I have supervised, read and approved this project work which I found adequate both in scope and quality in partial fulfilment of the requirement for the award of a BACHELORS' DEGREE in AGRICULTURAL ENGINEERING.

-------------------------------- 30/1/98

Engr. B.A. Alabadan
(PROJECT SUPERVISOR)

DATE

-------------------------------- 31-01-98.

Dr. Akin Ajisegiri
(HEAD OF DEPARTMENT)

DATE

(EXTERNAL SUPERVISOR)

DATE

DECLARATION

I hereby declare that the project work was absolutely conducted by me, under the close supervision of Engr. B.A. Alabadan during the 1996/97 academic session, and to the best of my knowledge it has never been submitted elsewhere before now.

------------------------------ ---------------

Ejele D.O. (90/1485) Date.

DEDICATION

To the one I love the most; GOD ALMIGHTY, in whom also I live, move and have my being, for equipping me with strength and courage coupled with His all- surpassing wisdom and grace, all through my university education.

Also to my parents, Lt.Col. (rtd) & Mrs. Paul Ejele; for your love, faith and patience in bringing out the best in me.

I LOVE YOU!

ACKNOWLEDGEMENT.

I am greatly indebted to my supervisor, Engr. B.A. Alabadan, for his faith in me and patience in carrying me steadily through the period of my research work. Thanks for all your invaluable contributions and suggestions.

I am grateful to my Head of Department, Dr. Akin Ajisegiri, for his fatherly role and innovative policies. I also want to express my gratitude to all the lecturers in the department of Agricultural Engineering, F.U.T. Minna (you are all wonderful), and also my good departmental-assistant friend, Mallam Audu ("Deputy").

Many thanks to my friend and professional colleague, Engr. Idrisu J. (you are a pack of potentials).

I also appreciate my friends and members of the "Youths For The Nations" club, for their support and proper influence.- "Masters", "MZ, the perfect G", "ASQ King", Theo ("Presido"), Kate B. (M.K.B), Florence ("Lady F"), Hannatu ("the Queen of Sheba"), Martha (M.D), Mary ("Mama Oye") and Toyin ("Baba Oye"). You are all wonderful. A special bunch you are.

Special thanks to my very special friend, Ayodele Ireti Adeniyi (I.R.A), "you are such a rare gift (God must have sent you down from heaven)", and to her mum, Mrs Becky Adeniyi (Mummy), words cannot adequately express my gratitude for all your faithful concern, care and faith. God bless, Ma.

Finally, I want to express my deep gratitude to my immediate family members; Pastor & Mrs Chris Ejele (PRO), Lee Luv, Dupe Tijani (Mrs), Paulyn ("Tinrin"), Ofure ("my black beauty"), Odia ("Sofe") and also Glory ("omo mo"). I thank you all for allowing me be me, and accepting me just the way I am. Inspite of our so many differences, ours' is a family where love reigns and champions are raised. Thanks a lot.

Lastly, I want to thank Bimbo ("Mama"), Akin Thompson (for doing a beautiful job on this presentation), and finally Nonye.

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The project work is a quantitative assessment of storage losses in Roots and tubers. It focuses on the types and extent of damage incured in roots and tubers during storage and relates them to the eventual loss levels in Roots and tubers annually in the selected Local Government Areas in Niger State (Gurara, Shiroro, and Wushishi Local Government areas), who are notable producers of these crops.

Results showed that for the selected roots and tubers (Yam, Cassava and sweet Potatoes), the levels of losses incured annually in each of the selected Local Government areas were related to the method of harvesting the crops, methods of handling harvested crops and methods of storage of harvested crops.

Loss levels of about 20.6% (of total stored products) for Yam tubers, 24.3% for Cassava and about 37% for sweet Potatoes were recorded annually for Gurara Local Government Area. Similarly loss levels of about 20.9% for Yam tubers, 15.8% for Cassava and 4.6% for sweet Potatoes (of total stored products) were recorded annually for Shiroro Local Government area. Whereas Loss level of about 22.85% for Yam tubers, 32.84% for Cassava and 32.61% of total stored sweet Potatoes products, were recorded annually for Wushishi Local Government area

The report concludes with practicable recommendations on how these loss (damage) levels could be effectively reduced.

TABLE OF CONTENTS

CHAPTER ONE

1.0 GENERAL CONSIDERATION: WHY ATTENTION TO STORAGE?

The problem of feeding the world's increasing population neither begins nor ends on the farm, since it involves the whole social and economic structure of each nation./a reduction in the existing imbalance of protein and calorie intake in developing countries will not be solved only by existing campaigns on food production, saving farm deterioration or waste what has been harvested and effectively distributing the world's harvest of food to areas of requirement, are essential aspects which have not been given enough attention.

1.1 THE CONCEPT OF LOSS AND ITS DEFINITION.

Post-harvest loss is defined as the cumulated result of damage resulting from or caused by abiotic, biotic or anthropic (human) factors during the sequence: maturation, harvesting , handling and processing.

COMPONENTS OF LOSS.

Having defined loss, a look at the components of loss is important. These include:

- Bruised or damaged crops
- mould damage
- loss of viability
- loss of weight
- insect/pest infestation
- rodent damage
- nutritional value level

Losses may be either quantitative (physical loss of substance as shown in reduction of weight or volume) or quantitative (as seen in fall in nutritional value level) and they result from the following factors:

I. physical factors; including mechanical damage, damage caused by high and low temperatures

II. physiological factors; including respiratory losses (as well as water losses) and losses due to sprouting

III. pathological factors i.e. micro-organism attack.

IV. Entomological factors, i.e. pest attack.

1.2 THE IMPORTANCE OF ROOT AND TUBER CROPS.

The most important root and tuber crops in Nigeria are:

Cassava (*Manihot esculenta*), Yam (*Discorea spp*), Sweet potatoes (*Ipomea batatas*), Cocoyam (*Xanthosoma spp*), and Irish potatoes (*Solanim tuberosum*).

A thin dividing line places these crops into these two broad food classifications, however, root and tubers are almost always considered together owning to overwhelming similarities in their form and utility.

Root crops, for example, cassava have their food materials developing from the root system i.e. root food crops are actually a form of developed root systems. They also get propagated vegetatively (stems or shoots).

Tuber crops, for example, yam, on the other hand develop from the shoot bud, underneath the soil, i.e. they develop differently from the root system. They are propagated sexually (seedlings).

1.3 OBJECTIVE OF STUDY.

Against the backdrop of the earlier stated fact as to the need to save from deterioration or waste what has been harvested, this research was carried out with the following objectives in mind:

I. to identify the methods of storage and the facilities available for the storage of roots and tubers in Niger state

II. to identify the sources of losses in the handling of these food crops with particular emphasis on loss associated with food storage

III. to quantitatively estimate the quantity and extent of roots and tuber crops loss annually in storage in the Local government areas selected

IV. to quantitatively assess the loss in terms of reduced nutritional level and change in physical state of the food material (thereby fully ascertaining the extent of damage), by carrying out a laboratory scale practical analysis on the roots and tubers in question (i.e. showing their characteristic behavior in a typical storage environment).

V. Give practicable suggestions, in relation to suitable storage structures and safer handling methods, as to how to minimize storage losses in these areas.

1.4 SCOPE OF STUDY.

This study encompasses the quantifying of losses in stored roots and tuber crops namely;

The research work covers three Local Government areas in Niger state, namely; Gurara, Shiroro, and Wushishi Local Government areas.

Along with the field work, a practical laboratory analysis was carried out to investigate the characteristic behavior of the selected roots and tubers in storage, taking into consideration such parameters as;

I. storage temperature,

II. relative humidity of storage environment,

III. length of time of storage.

The investigation focuses on how these tubers deteriorate by correlating these parameters with the earlier mentioned components of loss, then relating this loss pattern to obtainable conditions in the selected Local Government areas.

1.5 JUSTIFICATION.

It has been observed that storage losses of tropical roots and tubers are enormous and very important from both economic and nutritional stand points. As a result of their bulky and irregular shape, they become particularly difficult to handle during transportation, marketing and storage. Losses of up to 50% of the total quantity of stored yams, 90% in stored sweet potatoes, and 60% in stored cassava have been recorded (Adesuyi; 1979, Caursey and Booth; 1972).

Similarly in Niger state, agricultural development project figures for losses in the state, reveals a strong correlation with the afore-stated figures. It places loss level in total production of yam at 50%, and cassava at 65% (Niger State ADP, 1992). These problems, though technologically complex, may respond well to a rational scientific approach and thus a great need to increase our knowledge of these important food crops.

Niger state is one of the major root and tuber producing states in Nigeria, and the three selected Local Government areas (Gurara, Shiroro and Wushishi) form a high percentage of the roots and tuber producing areas in Niger state (Niger state ADP, 1992).

CHAPTER TWO

ROOTS AND TUBERS: THEIR IMPORTANCE, METHODS OF STORAGE AND PRIMARY CAUSES OF LOSS IN THEIR STORAGE.

2.1 IMPORTANCE OF ROOT AND TUBER CROPS.

The most important root and tuber crops in Nigeria are ; cassava (*Manihot esculenta*), yam (*Discorea spp*), sweet potatoes (*Ipomea batatas*), cocoyam (*Xanthosoma* & *Colocasia spp*) and Irish potatoes (*Solanium tuberosum*).

They are very important staple food crops as they form a major part of the diet of millions of Nigerians, contributing about 15% of the daily energy requirement (Olayode et al; 1979). To fully appreciate their place and position in the Nigerian context, we shall take a closer look at some of these roots and tubers.

2.1.1 CASSAVA (*Manihot esculenta*):

Cassava is a major food crop in Nigeria. It is eaten in different forms and widely cultivated throughout the country, because of its high yield and low agronomic requirement. About 50% of root crops production in the tropics is cassava, accounting for about 12.5 million tonnes annually in Nigeria alone (Ene, 1986), which cannot be normally kept in the fresh state for more than 2-5 days after harvest. As a result, the crop is commonly left in the ground until required and consumed or processed as soon as lifted. Thus, globally, about 0.75 million hectares of land are occupied unnecessarily by the standing crop, thus limiting the farmer from putting his land to other uses immediately the cassava attains maturity. Similarly, during the period the crop may continue to grow, the roots decline in quality (Doku; 1969) and increase in disease susceptibility (Wholey; 1978 and Iromine, 1969). This inability to store cassava presents serious problems in the marketing of the crop, and results in extremely heavy but unrecorded losses.

2.1.2 YAM (*Discorea spp*).

Nigeria is the largest producer of yam in the world, with an annual harvest of about 16.75 million tonnes (Ene; 1986). It is widely an accepted food crop in the country. Yam is grown once a year and so proper storage is imperative. While it is generally believed that yam problems of rotting and sprouting cause the greatest spoilage to yams in storage. A loss of about 30-45% of an estimated 16.75 million tonnes of yam produced yearly in Nigeria, results in monetary losses of up to one billion naira annually (Ene; 1986).

In a review of storage losses, Caursey (1966) illustrated how these losses vary considerably in magnitude and nature from country to country, species to species and even from variety to variety. Loss in weight ~~(according to Caursey)~~ of 10-20% after only 3 months of storage, and 30-60% after 6 months, are not unusual, even for sound tubers. Even greater losses occur through infection, by rotting organisms. The entry of these pathogens occur through wounds or cuts and natural openings on the surface of the tubers.

However, it is equally true that while the total amount of available food may be seriously diminished during storage, that which remains is usually of good quality. This is in contrast to the situation reported above (2.1.1) for cassava, where root crops become completely unacceptable.

2.1.3 POTATOES AND SWEET POTATOES (*Ipomea batatas* *and* *Solanium tuberosum*).

These also form an important part of Nigerians' chef, chiefly produced in the seemingly temperate weather conditions of Jos (Plateau state) and also in most parts of Northern Nigeria.

Whilst their storage has been extensively studied under temperate conditions, little or nothing is known concerning the storage behavior of these crops under tropical conditions. Even in temperate conditions in the U.S.A and Europe, where sophisticated techniques of controlled environmental storage have been developed for these crops, considerable losses are known to occur. Reported losses for sweet potatoes and Irish potatoes respectively are 19% and 16% during storage and wholesaling, 4% and 4-6% during retailing and 12% and 18% within the household. These loses would certainly be greater under tropical conditions where less effective storage methods are used.

2.2 METHODS OF STORAGE FOR FRESH ROOTS AND THEIR TUBER CROPS.

Storage defined as "the setting aside for future use of sparable items" (Ajisegiri; 1987) is imperative since not all the roots and tuber crops produced are consumed or processed immediately after harvest, thus saving from deterioration or waste, what has been harvested. Storage is an essential aspect in the entire cycle of food production.

Farmers have their methods of storing harvested roots and tuber crops. Some of these the farmers are convinced that the new ideas are better than their existing practices, or made to improve on the existing ones (Ajisegiri; 1992).

2.2.1 STORAGE OF CASSAVA.

I. STORAGE IN SAW-DUST.

Here, suitable containers such as wooden boxes, paper cartons and woven baskets are filled with clean, moist saw-dust. The harvested cassava tubers are then buried in layers within the saw-dust. The last layer of saw-dust is made 3-4 inches thick. The saw-dust is kept constantly moist.

Garri, 'eba', 'akpu' made from cassava tubers after 10-12 weeks of storage in saw-dust were very acceptable and compared favorably with those from freshly harvested cassava. The control tubers (un-stored) developed black streaks after 7 days, became mouldy, and malodorous after 10 days, while they completely rotted in 2 weeks.

II. TRENCH-STORAGE.

While the saw-dust method of cassava storage will store small quantities, the trench storage method can be used to store several tonnes. A trench of 2 x 1.5 x 1 metres will store about 750-1000 kgs of cassava tubers.

This technique involves the digging of a trench of about one metre in height, with variable length and breadth depending on the quantity of cassava tubers. The cassava tubers are then packed into the trench with alternate layers of palm or raffia fronds.

Cassava roots tubers so buried should not be bruised and should carry a stalk of 5-6 cm. The last layer should be covered with palm/raffia leaves and soil. The soil is kept moist by wetting with clean water when the top is noticed to be drying up. To prevent excessive evaporation of water from the trench, a shed of about 2-2.5 metres high is built over the trench. Cassava tubers so stored have kept fresh for 10-12 weeks.

III. CLAMP-STORAGE.

Clamps are constructed by placing the roots in cone-shaped heaps and covering them with straw and soil but at the same time providing ventilation through a pipe which is placed at the top-most part of the construction. Cassava thus stored lasts for about 2-3 weeks (Booth, Trials on this method have indicated that conditions conducive for both curing and storage can also be obtained in these units, provided internal clamp temperature remains below 40°C and roots are prevented from drying out (Booth, 1973).

IV. GARRI STORAGE.

The critical factor in gari storage is the moisture content. When properly dried to 10-13% m.c, cassava (in the form of gari), well-packed and sealed in polythene will store well for 4-6 months as long as moisture is prevented from entering the bag. For a good support, the polythene bag should be placed inside a jute bag or a hessian bag.

Well-dried gari will also store well for a long time in sealed kerosene tins and drums, as well as plastic containers. White gari stores better than yellow gari.

V. STORAGE IN REDUCED TEMPERATURE.

The effect of temperature ranging from refrigerated conditions to room temperature on cassava has been studied (Jean and Humphries, 1972). Fresh cassava was stored for 4 weeks at 3°C, 12°C and room temperature (about 25°C). The total loss, dry matter content, starch, sugar, pH, total acids, vitamin C, peroxide, catalase and dehydrogenase activities were followed. From their observations, cassava stored best at 3°C with only a total loss of 14% after 2 weeks of storage, and 23% after 4 weeks. Deep-freezing is an effective method of storing cassava, and in Brazil, Colombia, and Puerto-Rico, limited quantities are preserved commercially in this way (Jean and Humphries, 1972). The method can be used for large scale preservation of cassava roots.

These structures have an advantage of adequate security over the stored cassava and also that of high storage capacity. Similarly, insect attack is reduced.

On the other hand however, the initial investment is quite high, and there must be a constant power supply for proper functioning of the cold storage equipment. Any interruption in the power supply leads to condensation of moisture on the tubers leading to deterioration (Gonzalez, 1972), thus placing this method out of the reach of peasant farmers.

2.2.2 YAM STORAGE.

I. STORAGE IN VENTILATED SHEDS (BARNS).

This is the most common method of yam storage in Nigeria. It could be in the form of a

The sides of the shed are made of smooth wall about 1.2 metres high and a wire mesh to prevent rodent and bird entry. The roof is made of thatch to keep the shed cool. The unbruised and undamaged tubers are arranged and slatted platforms of shelves in such a way that the sprouting ends can be easily reached. Sprouts are normally removed from thee yam as soon as they are detected. Yams have been stored successfully with less than 10% spoilage for 4-5 months by this method.

II. COOL-STORAGE.

Storage of undamaged, unbruised yam tubers at a reduced temperature of 14°C to 16°C and relative humidity of 60-75% has been found to check sprouting and rotting of the tubers for 8 months. Weight loss was also reduced too about 50%.

III. GAMMA RADIATION.

Gamma radiation of yam tubers has also been investigated. This technology involves the use of ionizing radiation from a gamma source such as cobalt-60. It has been proven that a dose of 7.5-12.5 Krads will completely suppress sprouting (with no side effects) for 8-9 months.

Although the technology is highly specialized with a high initial cost outlay, it is very effective method of yam storage. Treated yam can be stored in ambient conditions and they will retain their quality.

IV. YAM CHIPS AND YAM FLOUR STORAGE.

In some states in Nigeria, about 20-25% of total yam harvested are processed into dried yam chips. Yam chips with 13-15% moisture content can be effectively stored in polythene lined jute bags. If insect infestation is detected, fumigation should be carried out at one tablet of phostoxin per bag. Dried yam should be prevented from re-wetting by rain, or water, as this will raise its moisture content above safe levels for storage and it will become mouldy.

Flour from yam chips properly dried to 13-15% m.c should be stored in polythene-lined jute bags. The milled product can also be stored in suitable containers such as tins and drums that will prevent moisture and insects from getting into the flour.

A new technique described as the **"cold shock treatment"** has recently been tested for pre-storage applications of yam flour and other flours. Grains can also be similarly treated. Briefly, the method consists of packing the product in thick-gauge polythene bags, which are sealed up and put in a freezer at -4°C to -10°C for 2-days, and then taken out for storage in small packages of 2-5 kgs. Products so treated have been stored for up to 18 months without deterioration.

2.2.3 STORAGE OF SWEET POTATOES.

I. QUONSET-TYPE STORAGE.

The Quonset storage building is constructed with galvanized metal sheets. The metals are joined together using planks or wood and nails in order to obtain a half-circular structure with both ends of the construction touching the floor or ground (Wagner, Burns and Paterson, 1983).

Before the storage of the sweet potato tubers, they are first of all cured for 7 days at 30°C and 95% relative humidity. The tubers are then packed in crates which have black, double-walled, plastic covers installed inside it. The Quonset-type is equipped with a fresh air exchange system. Under the storage condition, the tubers could be preserved in good condition for more than 3 months without change in taste, colour, moisture content and others. Sprouting within this period is insignificant (Umeh, 1987).

The advantage of the Quonset-type storage is that the plastic-covered structure can be tailored to fit the size of the growers operation and the structure can be located near points of production thereby minimizing handling costs.

Its disadvantage is that the material required for construction of this structure is relatively expensive.

II. PIT STORAGE.

Pits of about 0.5m in length by 0.5m in width by 0.5m in depth are dug. The bottom of the pit is then lined with dry grass or coconut shell, or dry shells. Before storage, the tubers are cured for 4-6 hours under the sun, and they are dusted with wood ash. They are packed in the pit up to 15cm from the ground level and covered lightly with dry grass and top soil. Finally, the pit is covered with raffia mat to keep off water (Umeh, 1987).

III. STORAGE IN SAW-DUST.

Experimental results have shown that sweet potato tubers can be stored in sterilized or un-sterilized moist saw-dust for a period of up to 4 months. The tubers were stored in baskets, and 10% sodium hypochlorite was used to disinfect the tubers before storage (Umeh,1987). The are noticed. Bantale and Thiabendazole (TBZ) could also be used for disinfecting, but they are quite expensive (Nwodu, 1990).

2.3 CAUSES OF LOSS IN ROOT AND TUBER STORAGE AND THEIR AVOIDANCE.

Post-harvest losses in roots and tubers are manifested in the loss of quality or quantity of the produce, or a combination of both. These losses result from:

a) physical,
b) physiological,
c) pathological,
d) entomological

factors or various combinations of these factors. As already discussed, the concept of loss is defined as the cumulated result of damage caused by Abiotic, Biotic or Anthropic factors, as related to the above listed factors. These factors are further treated.

2.3.1 LOSSES DUE TO PHYSICAL FACTORS.

I. MECHANICAL DAMAGE.

Losses due to mechanical damage are frequently over-looked and because of the added complexity of secondary physiological and pathological losses, are difficult to estimate. Mechanical injury takes many forms, including;

a) deep cuts and bruises
b) puncturing (of skin layer)
c) piercing (of the top few centimetres by sharp objects)
d) bruises and bursting
e) scalding.

They arise from all stages in the history of the produce from post-harvesting operations, through harvesting, handling operations such as grading, packing and transportation, to exposure in the market, and finally in the house. An example of the possible magnitude of loss through direct mechanical injury was revealed in recent surveys in Britain, which showed up to the stage of grading on the farm. 33% of the potato chip is so seriously damaged that it is only fit for stock feed, while a further 12% loss from damage can occur during transit from farm to shop. In addition to causing such direct losses, less immediately obvious damages increase

II. DAMAGE CAUSED BY HIGH AND LOW TEMPERATURE.

Many tropical perishable food commodities including root crops are subject to chilling or low temperature injury. Thompson (1992) and Caursey (1968) have shown that yams suffer from chilling damage at 12°C or below. This is also true for sweet potatoes. It has also been suggested (Ingram and Humphries, 1972) that chilling damage may also occur in cassava stored at 12°C. The extent of chilling damage is usually dependent on a time/temperature interaction, and while damage may be manifest in many ways, the most common symptoms are: internal tissue breakdown, increased water loss, susceptibility to decay, failure to sprout and failure in culinary qualities.

Damages may also result from exposure to excessively high temperatures during harvest, handling, or in storage. It is generally recognised that potatoes dug in hot weather and exposed to the sun for a relatively short time are subject to sun scald, which increases both storage and transit losses. In addition, excessively high temperatures may induce black heart, a disorder caused by **asphyxiation** of the central cells (Burtan, 1966 ; Booth and Proctar, 1972). Sweet potatoes are reported to be less susceptible to this type of damage, but it is thought to occur in yams, where it has been shown in West Africa that the internal temperature of tubers exposed to the sun may reach 45-50°C. Temperatures during storage may also considerably influence the culinary qualities of root crops.

Generally, the temperature much greater or less than the recommended optimum usually causes detrimental quality changes.

2.3.2 LOSSES DUE TO PHYSIOLOGICAL FACTORS.

I. WATER AND RESPIRATORY LOSSES.

Because produce is alive, natural endogenous respiratory losses of dry matter together with transpiratory or wilting ;losses of water will always occur, while data exists on storage weight losses, some of which were quoted earlier, and which are largely assumed to be due to water loss, less information is available on the magnitude of respiratory losses. The process of potatoes stored under controlled conditions have been extensively studied (Burtan, 1966). Losses in dry matter from potatoes stored at 10°C are approximately 1.2% during the first month, 0.8% per month thereafter, but rising up to 1.5% per month when sprouting is well advanced. Sweet potatoes stored under controlled conditions have been found to loose water to dry and CO_2 in such a manner that the ratio of water to dry matter changes very little. It is well of these crops can be expected to be much higher when stored under loss controlled conditions in the tropics.

In the tropics, Caursey (1969), emphasized the importance of endogenous metabolic losses during yam storage, which he stated accounted for an approximately one-third of the total weight loss of sound tubers during storage.

II. LOSSES DUE TO SPROUTING.

With the exception of cassava roots which are organs of perennation and not propagation, a further physiological cause of loss in storage is that of sprouting. Caursey (1966) shared that while sprouting of yam stored in different regions of Nigeria was very variable, it could reach 100% after 4 months of storage.

Sprouting of potatoes (Burtan, 1966), sweet potatoes (Kushman and Wright, 1969) and Aroids (Gollifer and Booth, 1973) also occurs causing increased moisture and respiratory losses. Sprouting usually increases with increased storage temperature up to a certain maximum.

2.3.3 LOSSES DUE TO PATHOLOGICAL REASONS.

Attack by micro-organisms (Fungi, bacteria, and to a less extent, viruses), is probably the most serious causes of post-harvest losses in tropical root crops. However, it must be remembered that physical or physiological damage frequently predisposes material to pathogenic attacks.

Pathogenic losses may in general be divided into those reducing the quantity of sound produce and those reducing the quality of the produce.

Quantitatively pathogenic losses result from the rapid and extensive breakdown of host tissue by micro-organisms. The pattern of attacks usually an initial infection by a broad spectrum of weakly pathogenic or saprophytic organisms, which grow on the dead or moribund tissue remaining from the primary infection (Thompkins, 1952; Turner, 1959). It must be emphasized however that these secondary invaders play an important role in post-harvest pathology, frequently serving to multiply and exaggerate the damage started by primary pathogens.

Qualitatively pathogenic losses are typically the result of blemish or surface diseases which render the produce less attractive and so reduce its market value. In yams, sweet potatoes and potatoes, internal blemish diseases reported as caused by viruses also reduce the final

The occurrence and magnitude of losses due to pathogenic micro-organisms are very variable and dependent on several factors. As many post-harvest pathogens are wound parasites, one of the major factors governing the incidence and magnitude of such losses is the physical condition of the produce.

A wide range of micro-organisms has been isolated from diseased roots and tubers. Some of these are listed below;

TABLE 1: PATHOGENS ASSOCIATED WITH POST-HARVEST DETERIORATION OF ROOTS AND TUBER CROPS IN NIGERIA.

ORGANISM	CROP				
	CASSAVA	YAM	COCOYAM	SWEET POTATOES	IRISH POTATOES
Fusarium solani	−	+	+	+	−
Fusarium moniliformae	−	+	−	−	−
Botryodiplodia theobromae	+	+	+	+	−
Sclerotium rolfeii	+	+	+	+	−
Rhizopus stolonifer	−	+	+	+	−
Carticium rolfeii	−	−	+	−	−
Rosellina bunoides	−	+	−	−	−
Lasiodiplodia theobromae	+	+	−	+	−
Penicillium spp	−	+	−	+	−
Macrophomina phaseoli	−	+	−	−	−
Serratia spp	+	+	+	+	−
Aspergillus niger	+	+	+	+	−
Formes lignosus	+	−	−	−	−
Hendersonula toruloidea	−	+	−	−	−
Erwinia Carotovora	−	+	+	−	+

KEY: + = PRESENT

− = ABSENT

(SOURCE: Booth, ~~storage of tropical root crops~~, 1978).

2.3.4 LOSSES DUE TO ENTOMOLOGICAL FACTORS (PEST ATTACK).

Post-harvest losses may also arise from pest attacks. These vary from insects, e.g. the potatoes' tuber moth, to larger animals such as rodents and monkeys while Nematodes are not normally considered as being of importance in stored produce. Thompson (1973) has recently shown that nematodes cause necrotic areas on stored yam tubers. These losses are however of minor importance as compared with those discussed earlier.

2.4 CONTROL OF LOSSES.

When considering the possible means of reducing post-harvest losses, it is essential to remember that living organisms are involved and that losses arise from assaults on their physical and physiological integrity. These losses may be reduced by various chemical and physical means and also try utilizing the produce immediately after harvest and so avoiding the need for storage.

In addition to considering technical means of reducing losses, the importance of social factors must not be forgotten. In many developing countries, educational and managerial standards are lower and financial resources restricted, thus fewer sophisticated facilities are available and food handling techniques are generally less satisfactory, resulting in substantially heavy losses.

Some of these control measures include:

2.4.1 LOSS AVOIDANCE.

In several tropical regions, the problem of root crop storage has been avoided because due to favorable rainfall distribution, the crops can be grown throughout the year. Thus, with regular planting programmes, a supply of fresh produce can be maintained. In other regions, continuous production is not possible, and even in areas where it may be produced, it is in the face of the continuous change from a substance to a cash crop economy, accompanied by increasing urbanization, became less satisfactory. Thus, some knowledge of the occurrence and cause of post-harvest losses of these perishable crops and some knowledge of appropriate storage and handling methods are necessary to reduce wastage and make possible the more economical utilization of supplies.

2.4.2 CHEMICAL CONTROL.

In addition to reducing post-harvest losses caused by diseases by adhering to good application of pesticides to the produce. Pesticides may be classified by methods of application into:

Fumigants,

Treated wraps,

Dips,

Sprays, and

Dust.

Dips, sprays and dust have been most commonly used with root tubers. Successful treatment depends on the use of compounds which are either fungistatic (bacteriostatic) or fungicidal (bacteriodal) at dosage rates that are not phototoxic.

A great many diverse chemicals have been used in reducing post-harvest losses/spoilage. Those reported to reduce storage losses in root crops include; Sodium Orthophenylphenate (SOPP), Borax, Captain, Thiabendazole (TBZ) and Benomyl (Nwodu and Nnwankiti, 1986; Adesuyi, 1977). Not in Reference

Also various waxing techniques have been experimentally shown to reduce post-harvest loss. The storage life of cassava for instance may be extended to 3-4 weeks by dipping the freshly harvested cassava root in liquid paraffin wax (IITA, 1977). Other chemicals such as Formaldehyde have been used on produce not intended for consumption, whilst the use of broad spectrum, systematic fungicides with very low toxicity such as Thiabendazole and Benomyl may show promises for the future.

In the tropics, little commercial use has been made of post-harvest chemical treatments. Often, chemicals are not readily available or are too expensive and frequently the methods of application are not consistent with normal handling specifications.

It is also true to say that compared with pre-harvest pesticides, little attention has been paid by manufacturers and research workers to the development of safe post-harvest chemicals to reduce food losses.

A further important caused equation in the limitation of the post-harvest use of chemicals is that of food additives legislation and control. Before being added to food crops, all chemicals should be rigorously screened and only used in strict accordance with the food additive regulations of the country concerned.

In addition to post-harvest chemical treatment, certain post-harvest diseases e.g. potato tuber blight and black rot of sweet potatoes may be reduced by pre-harvest crop applications of protectant or eradicant pesticides. Thus, for successful disease control;, the knowledge is necessary of the pathogens in involved, mode and time of infection, development of the pathogen in the host and the host/pathogen reaction, so that control methods may be optimally defined and true.

SPROUT SUPPRESSANTS.

Extensive work has been done on the control of sprouting in potato and sweet potato stored under controlled conditions in many developing countries by the use of chemical sprout suppressants. However, storage facilities suitable for the use of such chemicals are frequently not available in the tropics, and their use is also limited by economic and managerial factors. Also most sprout suppressants have an inhibitory effect on periderm formation and so if used, the introduction into stores should if possible be delayed until wound healing process is complete. In the tropics, the general practice is to simply break-off the sprouts at regular intervals as they appear.

2.4.3 PHYSICAL CONTROL.

I. REFRIGERATION.

As metabolic processes generally slow down with a decline in temperature, the use of refrigeration is usually recommended for reduction of water and respiratory losses during storage. Low temperature storage also slows down the metabolism of pathogens and so frequently arrests rotting. However, the pathogens are rarely killed, so that as the produce is returned to ambient temperature, rotting may recommence rapidly. Some pathogens are low temperature tolerant, thus the temperature required to kill the pathogens also causes the chilling damage to the produce (as discussed earlier). In addition to such technical factors, the use of refrigeration for storage of root crops in the tropics is at present limited by economic, managerial and social factors. However, a certain degree of control and reduction of storage temperatures may be achieved in simple storage structures by the use of shadings and simple ventilation techniques.

II. HIGH TEMPERATURE.

High temperature treatment of produce may in some instances be used to control storage diseases by killing the pathogens e.g. holding roots at temperatures greater than 38°C is reported to control black rot of sweet potatoes. Some pathogens especially tropical strains are however heat tolerant and the temperature required to kill the pathogens also damages the host (as discussed earlier).

III. HANDLING METHOD.

Gross mechanical damage can also be reduced by improving methods of crop harvesting and handling. As already mentioned, food handling techniques are generally poorly developed in the tropics and fresh produce is only too frequently treated as an inert object. Emphasis must be given to the proper packaging, especially if the produce is to be consumed far from the area of production. In general, boxes and cartons are considered far more suitable than large sacks for the handling and transportation of root crops in the tropics e.g. Thompson (1972) shared that transporting yams in cartons as opposed to stacking them loosely in lorries reduces the percentage rejected for export from 49.7% to 16.5%. while more emphasis is being placed on crop mechanization to reduce crop production cost, consideration should also be given to the increased losses which usually occur following the mechanical harvesting of root crops.

In addition to reducing storage losses through a reduction in physical damage, certain diseases may also be minimized by modified cultural practices. The application of such methods usually depends on a thorough knowledge of the epidemiology of the disease concerned e.g. the common scab, a serious market disease of potatoes can be controlled by the use of well-timed irrigation.

IV. CURING.

One of the most effective and simple means of reducing post-harvest water and pathological losses of several root crops is by curing. Curing is a wound healing process during which gentle skin strengthening also occurs. The process is stimulated by conditions of relatively high temperature and humidities (Table 2), and involves, firstly, **suberisation**, followed by the development of a wound periderm that is effective in retarding water losses and acts as a barrier against infection.

TABLE 2: CONDITIONS REQUIRED FOR CURING ROOT CROPS.

CROP	TEMPERATURE (^{0}C)	RELATIVE HUMIDITY (ε)	TIME (DAYS)	SOURCE
IRISH POTATOES	15-20	85-90	5-10	*BOOTH & PROCTAR (1972)*
SWEET POTATOES	30-32	85-90	4-7	*KUSHMAN & WRIGHT (1969)*
YAMS	32-40	90-100	1-4	*GONZALEZ (1972)*
CASSAVA	30-40	HIGH	—	

Length of time for curing cannot be definitely stated as it depends on many factors such as conditions of the crop at harvest, type of wound, season, storage temperature and relative humidity. In practice, curing period generally ranges between 5-20 days.

TABLE 3: PERCENTAGE WEIGHT LOSS DURING STORAGE OF CURED AND UNCURED ROOT CROPS.

CROP	DURATION OF STORAGE (DAYS)	% WEIGHT LOSS (CURED)	% WEIGHT LOSS (UNCURED)	SOURCE
YAM	150	10	24	*GONZALEZ (1972)*
SWEETPOTATOES	113	17	42	*THOMPSON (1972)*
IRISH POTATOES	210	50	54	*SMITH (1973)*

The merits of curing for reducing diseases losses in potatoes and sweet potatoes is well established and widely practiced. It has also recently been shown that the curing of yam tubers can reduce storage decay considerably (1972).

While it is not established whether the rapid post-harvest deterioration of cassava roots is caused by physiological or pathological factors or a combination of both as suggested by Ingram and Humphries (1972) recent work has shown that curing can considerably delay the on set of deterioration. It is important to remember that following curing, handling of produce should be reduced to a minimum so as to avoid further injury that may result in further losses. Also, it is important to realize that the risk of initiating bacterial soft rots is possibly greater during the curing period when both temperature and relative humidity are greater than at any other time.

2.5 CONCLUSION AND JUSTIFICATION.

As a general principle, only those root crops that are free from disease and that have been carefully harvested and handled should be considered for storage. However, such produce is not always available and even when produce is carefully selected, heavy storage losses frequently occur.

Other aspects which need to be borne in mind in any study of post-harvest loss include varieties of the same crop can differ markedly in their storage qualities and resistance to storage diseases. Such varietal variation within the same root crop have already been mentioned and it is felt that considerable advances could be made by the simple selection of varieties suitable for storage and transport as opposed to simply utilizing surpluses of varieties selected for other characteristics.

Recent attention to internal trade in tropical root crops has perhaps served to emphasize our lack of knowledge of the handling and storage behavior of these crops e.g. 50% or more of the yam and tanma (aroid) shipment in the Chicago market is often discarded before marketing, even the quality of the marketed produce is often inferior (Burton, 1970). Most of these losses can be attributed to spoilage caused by various micro-organisms (Burton, 1970). It has been pointed out above how such losses may often originate in sites of mechanical damage and how they may be reduced in tropical root crops by improved handling and by curing of produce.

Conclusively., it is seen that post-harvest losses of tropical root crops are enormous and very important from both economic and nutritional stand points. Little or no information is available concerning the almost complete lack of storage ability of cassava root. Little attention has been paid to the edible aroids and even those crops such as yams, sweet potatoes, that have received more scientific attention, losses are still considerable. Although, these problems are technologically complex, there are however indications that they respond well to a rational scientific approach and thus there is a great need to increase our knowledge of this important group of food crops, thus the justification of this project.

CHAPTER THREE

3.0 METHODS AND MATERIALS.

This project involves:

1. a laboratory analysis of roots and tubers
2. questionnaire administration
3. oral interview.

3.1 LABORATORY PRACTICAL ANALYSIS.

A laboratory scale practical analysis was used to determine the nature and extent of damage on roots and tubers in storage and a prototype assessment of the effect of such conditions as:

a) storage temperature

b) relative humidity of storage environment

c) length of storage period.

On the storage quality of roots and tubers in storage, the following parameters wee taken into consideration, to enable a proper understanding of their behavioral trend in storage.

1. Weight changes in roots and tubers after storage period
2. changes in body out-look of tubers during the storage period
3. changes in smell (odour)
4. changes in nutritional value.

3.2 DATA COLLECTION THROUGH QUESTIONNAIRE ADMINISTRATION.

Questionnaires reflect information as regards:

1. methods of harvesting,
2. storage structures available for storing roots and tuber crops,
3. storage methods,
4. estimated quantity of roots and tubers before and after storage period,
5. problems associated with storage.

The questionnaires were administered to fairly literate respondents (farmers and traders) and in instances where respondents were unable to read and write, the method of oral interview became necessary.

3.2.1 ADMINISTERING THE QUESTIONNAIRE.

In the selected Local Government areas, 4 villages were selected from each area based on market information available as to the market inputs of those villages in terms of periodic inputs or proceeds into the main markets in their areas. Thus, the following villages were selected:

GURARA L.G.A.	MARKET DAYS
DIKO	SATURDAYS
GAWU-BABANGIDA	WEDNESDAYS
LAMBATA	EVERY FOUR DAYS
IZOM	EVERY FOUR DAYS
SHIRORO L.G.A.	
GWADA	SUNDAYS AND THURSDAYS
KUTA	MONDAYS AND FRIDAYS
SARKIN PAWA	MONDAYS AND FRIDAYS
FUKA	SUNDAYS
WUSHISHI L.G.A.	
ZUNGERU	SUNDAYS AND WEDNESDAYS
KALIKO	SUNDAYS AND WEDNESDAYS
WUSHISHI	FRIDAY
KIRIYA	FRIDAY

Based on the size of the selected villages, houses were picked (with fairly literate individuals), and given the questionnaire to fill. Similarly, traders, on the market days of their villages were also randomly selected and given the questionnaires.

Sample Size 77

3.3 ORAL INTERVIEW.

This fashion became necessary at instances where respondents were totally unable to read and write, thus assisted in the common local language (hausa), they were interviewed based on the information available on the questionnaire, and their responses were noted.

3.4 METHOD OF ASSESSMENT OF STORAGE LOSSES.

3.4.1 IDENTIFICATION OF DAMAGED ROOTS AND TUBERS.

The ways chosen to identify the damaged roots and tubers were basically a form of assessment and identification of a deviation from an already established physical state of a healthy root or tuber. These include:

a) Visualization; spoilt or damaged tubers sometimes are obvious to the sight of an observer.

b) Touch: a good tuber should have a hard and firm consistency as such any tuber showing a deviation as in being soft to touch were identified as faulty (rotten spots feel soft to touch).

c) Smell: the possession of a foul odour is a good indication of damaged or rotten tubers, probably due to fungal attack or microbial infection.

d) Taste: on cooking, the damaged set possessed sour tastes instead of the normal taste of roots and tubers.

3.4.2 ESTIMATING THE STORAGE LOSS.

The method for estimating the storage loss picks virtually most information from the distributed questionnaire.

Firstly, the population of the selected Local Government areas were obtained from the states' ministry for agriculture and natural resources, and from the male population and approximate value for the farming population was obtained for each local government area.

This population was then multiplied by the percentage of farmers cultivating a particular root or tuber crop (from questionnaire), thus obtaining the population of farmers cultivating that particular crop. Then this number was then multiplied by the estimated average harvest per farmer, obtained from the questionnaire, to get the total estimated quantity of harvested root and tuber crops in each local government area.

When this estimate was multiplied by the percentage of crops sold- stored- processed, the quantity of the total harvest sold- stored- processed was obtained.

Obtaining the total damage was done by multiplying the total estimated harvest by the percentages reported to have slight, medium, or heavy damages (in storage). When this was done for each local government area, an estimated qualification of storage loss was obtained.

The results also reveal that the population of the men folk exceeds that of the women folk. The male population gives an idea of the working (farming) population of these regions.

The result further reveals that the selected local government areas, fall amongst the most populated.

TABLE 3: POPULATION OF THE SELECTED L.G.A'S AND SOME OF THEIR IMPORTANT TOWNS.

L.G.A & TOWNS	MALE	FEMALE	TOTAL
GURARA	22,746	23,192	45,938
DIKO	3,249	2,106	5,355
GAWU BABANGIDA	1,860	1,746	3,606
IZOM	1,625	1,923	3,548
LAMBATA	1,749	1,905	3,651
SHIRORO	108,542	104,297	212,839
GWADA	2,617	2,004	4,621
KUTA	3,920	3,605	7,525
SARKIN PAWA	1,620	1,206	2,826
FUKA	1,117	1,262	2,379
WUSHISHI	102,871	92,549	195,420
ZUNGERU	5,007	4,026	9,033
KALIKO	2,227	2,220	4,447
WUSHISHI	4,670	3,790	8,460
KIRIYA	2,005	2,010	4,015

SOURCE: NATIONAL POPULATION COMMISSION, ~~NIGER STATE POPULATION BULLETIN,~~ 1995.

4.2 PRODUCTION CAPACITY OF THE L.G.A'S.

To properly estimate the production capacity of each of the important towns in the selected areas, it was first necessary to determine the percentage of the entire population that formed the farming class of these areas. This was done by determining from the male population, the category and percentage of males that were over 10 years of age, yet less than 65 years of age.(It was ascertained accurately that the farming class of most of these villages

TABLE 4: THE FARMING POPULATION OF EACH TOWN IN SELECTED AREAS.

TOWN	ENTIRE POPULATION	MALE POPULATION	% OF MALES BETWEEN 10-65 YRS	FARMING POPULATION
GURARA LOCAL GOVERNMENT				
DIKO	5,355	3,249	65%	2,306
GAWU BABANGIDA	3,606	1,860	72%	1,339
IZOM	3,548	1,625	68%	1,105
LAMBATA	3,651	1,749	69%	1,206
SHIRORO LOCAL GOVERNMENT				
GWADA	4,621	2,617	69%	1,805
KUTA	7,525	3,920	67.55%	2,647
SARKIN PAWA	2,826	1,620	68%	1101
FUKA	2,379	1,117	71%	739
WUSHISHI LOCAL GOVERNMENT				
ZUNGERU	9,033	5,007	70%	3,504
KALIKO	4,447	2,227	75%	1,670
WUSHISHI	8,460	4,670	69%	3,222
KIRIYA	4,015	2,005	65%	1,303

NIGERIA POPULATION COMMISSION BULLETIN, 1995.

After the farming population for each of these towns was determined, it was again necessary to find out the average production (harvest) per farmer in all of these local government areas, before the production capacity was finally deduced. The table below reveals the average production per farmer, in tonnes, in some of these towns.

TABLE 5: **AVERAGE HARVEST PER FARMER IN TONNES.**

TOWN	*CROP*		
	YAM	CASSAVA	SWEET POTATO
GURARA LOCAL GOVERNMENT			
DIKO	10.65	1.39	1.04
GAWU BABANGIDA	7.325	1.11	0.624
IZOM	8.518	0.435	0.604

TOWN	*CROP*		
	YAM	CASSAVA	SWEET POTATO
SHIRORO LOCAL GOVERNMENT			
GWADA	12.73	1.730	1.005
KUTA	11.695	1.555	0.982
SARKIN PAWA	13.746	1.924	0.994
FUKA	11.732	1.004	0.479
WUSHISHI LOCAL GOVERNMENT			
ZUNGERU	14.85	1.005	0.469
KALIKO	16.35	1.110	0.590
WUSHISHI	14.92	1.050	0.549
KIRIYA	16.005	0.540	0.500

From table 5, an average harvest per farmer in tonnes, annually for each of the local government areas can be deduced.

TABLE 6: AVERAGE HARVEST PER FARMER IN TONNES.

CROP	SHIRORO	GURARA	WUSHISHI
YAM	12.48	8.37	15.53
CASSAVA	1.553	0.848	0.926
SWEET POTATO	0.865	0.800	0.527

From table 6, Wushishi local government area is shown to take the lead in yam tubers production, followed by Shiroro local government area. The reason for this is not far-fetched. These areas are dominated by the '**gbagyi**' tribe (in some cases rendered '**gwari'**) with a known repute for large scale yam production. As a matter of fact, the average 'gwari' farmer commercializes his yam production as he not only produces on a subsistence level, but also markets a great deal of his produce, whereas he farms the likes of cassava and sweet potatoes at a subsistence level as reflected on the annual harvest per farmer table, of these crops.

4.3 ROOTS AND TUBER STRUCTURES IN EACH LOCAL GOVERNMENT AREA.

From the questionnaires, the answers the respondents gave as regards the mode of storage of freshly harvested produces as well as the storage structures available in these areas, It was noticed that damages before storage were to varying degrees, as such classification was given to more or less broad list. It was noticed that these damage levels were either:

1. slightly bruised (from minor mechanical injuries),
2. mediumly cut (owing to greater levels of injuries such as piercing and cutting),
3. heavily cut (more pronounced forms of damages suchas rupture, bursting e.t.c).

From the questionnaire, a table showing these varying levels of damage was plotted, and is shown in table 9 below.

TABLE 9: PERCENTAGE DAMAGE BEFORE STORAGE IN THE L.G.A'S.

CROP	SLIGHT BRUISES (%)	DEEP CUTS [MEDIUM] (%)	DEEP CUTS [HIGH] (%)	UNDAMAGED (%)
GURARA LOCAL GOVERNMENT				
YAM	42.28	10.25	10.35	37.12
CASSAVA	45.55	9.25	15.05	30.15
SWEET POTATOES	30.50	20.80	16.2	32.5
SHIRORO LOCAL GOVERNMENT				
YAM	52.68	10.25	10.65	26.42
CASSAVA	62.20	5.63	10.18	21.99
SWEET POTATOES	62.05	0.55	4.05	33.35
WUSHISHI LOCAL GOVERNMENT				
YAM	40.58	17.20	5.65	36.57
CASSAVA	45.22	10.62	22.22	21.94
SWEET POTATOES	30.84	20.52	11.61	37.03

The above table reflects a similar trend in all the L.G.A's visited. Respondents revealed that most produces get slightly bruised before damage. However it was observed that in most villages, farmers, being now enlightened, endeavour to prevent damages to the produces.

TABLE 10: FACTORS RESPONSIBLE FOR STORAGE LOSSES.

CROP	SPROUTING (%)	RODENT ATTACK (%)	FUNGAL INFECTION (%)	MOULDING & ROTTENING (%)	SKIN CHANGES (%)	THIEVES (%)
SHIRORO LOCAL GOVERNMENT						
YAM	13.05	26.55	15.55	26.00	16.00	2.85
CASSAVA	00.00	24.50	38.00	25.00	10.00	2.50
SWEET POTATOES	25.00	27.00	16.00	18.00	12.00	2.00
WUSHISHI LOCAL GOVERNMENT						
YAM	8.50	45.00	32.50	8.50	5.50	0.00
CASSAVA	0.00	18.50	40.00	15.00	20.50	6.00
SWEET POTATOES	15.00	13.00	20.50	30.00	18.00	3.50
GURARA LOCAL GOVERNMENT						
YAM	20.00	23.45	11.55	28.00	8.50	4.45
CASSAVA	0.00	20.00	35.50	20.50	21.50	2.00
SWEET POTATOES	18.50	26.50	24.00	18.55	17.00	1.50

It is important to note that some of these factors shown in table 10 could act on independent levels. However, most times, they are occuring simultaneously with one another. In other words, the actual damage is brought about by an inter-related combined effect of two or more of these factors. For instance, rodent attack could pave way for rottening of tubers, which could also ultimate in change of tuber skin.

Rodent attack and moulds & rottening were noticed to be the important factors in the consideration of causes of storage losses. The human factor (shown by 'thieves'), though not very significant (in comparison with other factors), is also one way that stored produces are lost, for instance, in Gurara l.g.a, Diko village, where under-scale thefts were frequent occurences this particular storage season.

These factors are now further pictorally represented to give a fuller impression of their magnitudes, as shown in figures I, II, and III.

Figures I, II, and III show a histogram representation of the various percentages these agents of storage damage to the crops in question, and also reveals in each of the local areas the particular factors that accounts for greater losses, year in, year out.

From all the diagram, it can be seen, for instance, that cassava tubers do not have problems with sprouting damages, but fungi attack and mould & rottening are clearly the most important storage damage factors.

The figures I, II, and III reveals that for yam storage, the most marked factors responsible for losses are rodent attack and mould & rottening, in that order.

These factors were then viewed side by side with the various structures available for storage, and it was observed that the tendency of their occurences increased with the more primitive methods, such as the pit storage as well as hanging, while the chances of their occuring were greatly reduced in the more modern methods such as barns and ware-houses storage. Figure IV shows the histogram representation of these storage structures as in their percentage usage distribution in all the L.G.A's (values shown in table 7).

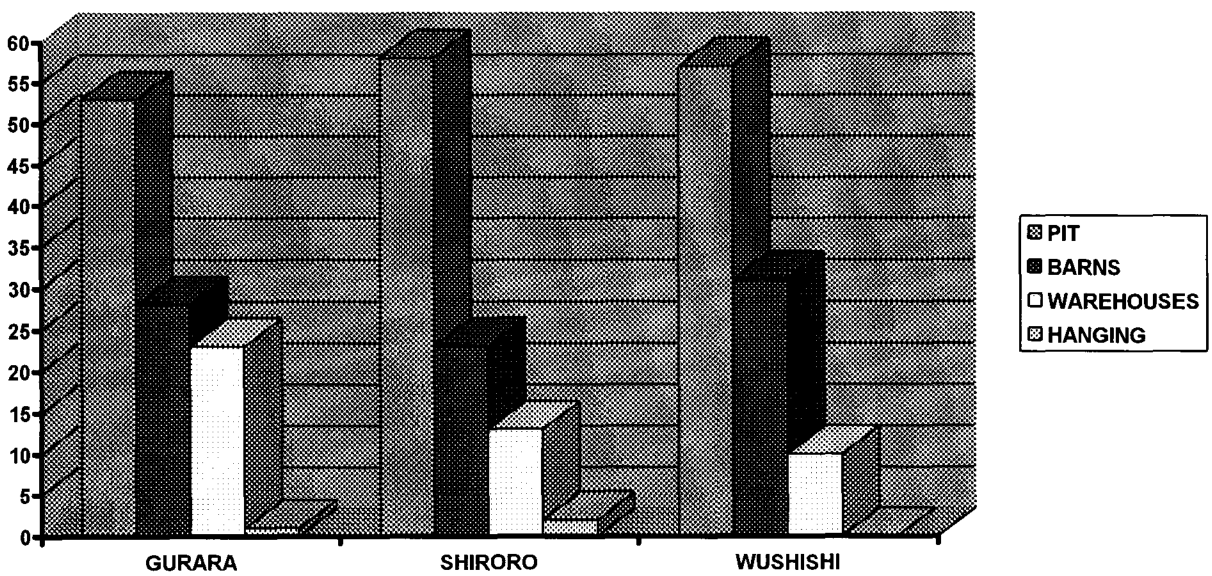

FIG IV : PERCENTAGE DISTRIBUTION OF STORAGE STRUCTURES.

The histogram reveals that in all of the local government areas, pit storage is still the most commonly used method of storing roots and tubers generally.

This primitive method of storage, though convenient for the farmers for obvious reasons (majorly economical), is chiefly responsible for the occassions of losses recorded in these regions and would be later on analysed. A shift to modern methods would greatly improve on the storability of the harvested roots and tubers.

4.7 ANALYSIS OF STORAGE LOSSES.

From the various percentages obtained from the questionnaires distributed, it became possible to analyse the magnitude of loss experienced in storage in all the various local government areas selected. However, before this was done, some basic assumptions were put into place, namely;

1. the random sampling of the selected towns iin these L.G.A's forms an accurate representation of the L.G.A they are situated, thereby implying that an average trend in these towns represents accurately the trend on the wider scale of the entire local government area.
2. In analysing the storage losses, only two of the recorded visible loss components (table 9) are actually responsible for the eventual recorded loss. These are:
   - deep cuts (medium), and
   - deep cuts (high).

It is from these parts that other damage components actually originate before taking the other dimensions mentioned in table 10.

Once these assumptions were clearly outlined, the actual estimation of the storrage losses begin in earnest. It would be neccessary from time to time to refer to the afore-mentioned tables and figures.

From table 4, an average percentage of males between the ages of 10-65 years (forming the farming population) for the entire L.G.A's were obtained.

TABLE 11 : AVERAGE PERCENTAGE OF MALE POPULATION BETWEEN AGES 10 AND 65 IN EACH L.G.A.

L.G.A	PERCENTAGES OBTAINED FROM IMPORTANT TOWNS.	AVERAGE FOR THE L.G.A (%)
GURARA	65, 72, 68, 69.	68.5
SHIRORO	69, 67.55, 68, 71.	68.88
WUSHISHI	70, 75, 69, 65.	69.75

TABLE 12 : MALE POPULATION AND ACTUAL FARMING POPULATION FOR EACH L.G.A.

L.G.A	MALE POPULATION	% OF FARMING POPULATION	FARMING POPULATION
GURARA	22,746	68.5	15,581

4.8 ESTIMATION OF STORAGE LOSS IN ROOTS AND TUBERS IN EACH L.G.A ANNUALLY

Taking into consideration the second assumption in section 4.5, it was necessary to view along side the total loss, the extent to which deep cuts (medium and high) affected the stored roots and tubers, as these were typically the situstions where the loss factors originated from.

CROP	TOTAL % OF CROPS WITH DEEP CUTS (MEDIUM & HIGH)
GURARA LOCAL GOVERNMENT	
YAM	20.6
CASSAVA	24.3
SWEET POTATOES	37
SHIRORO LOCAL GOVERNMENT	
YAM	20.9
CASSAVA	15.81
SWEET POTATOES	4.6
WUSHISHI LOCAL GOVERNMENT	
YAM	22.85
CASSAVA	32.84
SWEET POTATOES	32.61

TABLE 15 : ESTIMATED QUANTITY OF ROOTS AND TUBERS LOST ANNUALLY IN EACH L.G.A (IN TONNES).

L.G.A	YAM	CASSAVA	SWEET POTATO	TOTAL
GURARA	11,269.88	1,346.88	1,934.60	14,551.37
SHIRORO	78,003.37	7,328.52	1,196.82	86,528.71
WUSHISHI	96,756.76	8,327.41	4,712.49	109,796.66

SUMMARY OF RESULTS.

GURARA LOCAL GOVERNMENT AREA.

Quantity of yam tubers lost in storage annually	=	**11,269.89**	**tonnes**
Quantity of cassava tubers lost in storage annually	=	**1,346.88**	**tonnes**
Quantity of sweet potatoes lost in storage annually	=	**1,934.60**	**tonnes**

SHIRORO LOCAL GOVERNMENT AREA.

Quantity of yam tubers lost in storage annually	=	**78,003.37**	**tonnes**
Quantity of cassava tubers lost in storage annually	=	**7,328.52**	**tonnes**
Quantity of sweet potatoes lost in storage annually	=	**1,196.82**	**tonnes**

WUSHISHI LOCAL GOVERNMENT AREA.

Quantity of yam tubers lost in storage annually	=	**96,756.70**	**tonnes**
Quantity of cassava tubers lost in storage annually	=	**8,327.41**	**tonnes**
Quantity of sweet potatoes lost in storage annually	=	**4,712.47**	**tonnes**

4.9 GENERAL DISCUSSION.

A close look at the tables reveal a trend that has been discovered to be consistent for a period of time in these areas.

Generally speaking, the losses incured in storage in all of these regions can be attributed to a number of factors, the important ones being rodents attack for yams (recording about 26% in Shiroro L.G.A, 45% in Wushishi L.G.A, and 28% in Gurara L.G.A), fungal infection for cassava (with about 38% in Shiroro L.G.A, 40% in Wushishi L.G.A, and 35% in Gurara L.G.A), and a combination of sprouting, rodent attacks, and fungal infection in sweet potatoes.

It is interesting at this point to note that sprouting as a problem is restricted to yams and sweet potatoes, as it does not affect cassava.

Similarly, the distribution of the storage structures available in these areas for storing their harvested products have been known to affect the levels of losses recorded, (reccommendation for improvements are given in 5.4.1). The most common method is the pit storage in all of the L.G.A's (fig IV), however the barn and warehouse methods are also beginning to assume importance.

Conclusively, the levels of losses recorde for each crop shows that in all, for yam, about 20% of all stored in Gurara L.G.A is lost, 21% in Shiroro L.G.A, and 22% in Wushishi L.G.A. For

32% in Wushishi L.G.A . For sweet potatoes, 36% of the stored products are lost in Gurara L.G.A, less than 10% in Shiroro L.G.A, and close to 50% in Wushishi L.G.A.

These loss levels can however be reduced by improved handling and storage practises (discussed in section 5.4.1).

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS.

The figures of losses in roots and tubers in storage, reveal quite a substantial amount of yearly wastage of food produce resulting from any of these loss agents, or a combination of the agents, therefore more attention should be given to more effective methods of storing these important staple food items. In view of this, this chapter both summarizes the entity of activities reported in this work and also provides, ~~what I see to be~~ ways in which the quest for better storage techniques could be achieved.

Generally speaking, storage of roots and tubers in their original forms (i.e. roots as roots and tubers as tubers) for consumption, is fairly easily achieved only for a period of about six months (as observed in most villages visited). The roots and tubers are living and natural changes in weight and quality cannot be entirely prevented, as such sharply increasing losses were noticed (and are to be expected) after six months of storage.

From table10 t becomes obvious that in order to achieve good storage of roots and tubers (especially yam) the two most important factors to prevent are sprouting and rotting.

5.1 EFFECTS OF SPROUTING ON STORED TUBERS.

As a guide to reducing the effects of sprouting in tubers, a look at how it affects the tubers is necessary.

1. It reduces the food reserves in yams by translocating carbohydrates from the tuber into sprouts for metabolic purposes.
2. It increases the rate of respiration of stored yam, thereby increasing the rate of dry matter loss.
3. It causes an accelerated loss of moisture content of stored yams through the permeable surface of the sprouts, which results in the wilting of the tubers.
4. It causes substantial losses in weight in stored yam.
5. It makes the yam tuber become soft to touch (as noticed mainly in Wushishi L.G.A, progressively from the bottom to the head) thereby leading to the rotting.
6. It generally reduces the quality and palpability of the tuber which becomes fibrous and bitter (yams gotten from Kaliko, Kiriya and Kampani in Wushishi L.G.A are good examples) especially at the head region where the sprouting occurs.

5.2 EFFECTS OF ROTTING ON ROOTS AND TUBERS.

As earlier indicated (in table10), rotting poses an important problem and source of loss to storage roots and tubers, as

1. it increases the loss in weight of stored yams
2. it increases the rate or respiration, thereby increasing the rate of loss of dry matter
3. it adversely affects arability of stored yams, if to be used as seed yam
4. it causes partial or total loss of the root or tuber.

5.3 RECOMMENDATIONS FOR THE STORAGE OF ROOTS AND TUBERS BY FARMERS.

Having visited all the indicated towns in all the L.G.A's mentioned inthe fourth chapter of this work and having witnessed first hand the cultural practises in harvesting, handling and storing of roots and tuber, the following are recommendations for more effective storage loss reduction.

1. HARVESTING AND HANDLING:

Roots and tubers should be harvested and handled (including clearing and transportation to storage sites) with great care to avoid damaging or bruising them, as any damage or bruise will eventually become deterioration-start points (i.e rotting and infection would take advantage of the damaged regions).

Cassava for instance should be harvested with about 3-5 cm of the stalk attached to the tubers to ensure that the cut is well away from the actual tuber.

Handling the roots and tubers should also proceed with plenty of caution. For instance, if the storage sites are not on the farms, then transporting them to the sites of storage should be done in an organised manner as in using boxes and cartons aas opposed to stacking them loosely in lorries and carts. Thompson (1982) showed that transporting yams in cartons as opposed to stacking them loosely in lorries reduced the percentage rejected for export from 49.7% to 16.5%. while more emphasis is being placed on crop mechanization to reduce crop production costs, consideration should also be given to the increased losses which usually occur following the mechanised havesting of root crops.

In addition to reducing storage losses through reduced physical damage, certain diseases may also be minimised by modified cultural practises (however the application of such methods requires a great deal of technical 'know-how' as it will involve a thorough knowledge of the 'epidemiology' (study of diseases affecting crops in large numbers) of the disease concerned,

2. **STORING ONLY UNDAMAGED ROOTS AND TUBERS AND PROCESSING OR SELLING OUT DAMAGED OR BRUISED ONES.**

Human fallibility makes room for mistakes, no matter how on e is careful as such, some roots and tubers still get damagsd or bruised. It is advisable to use the damaged roots and tubers immediately after harvest, as in eating them, or selling them off immediately, or even relegate them to the numbers to be processed into other more stable forms e.g chips or flours. Only the unbruised and undamaged ones, having greater susceptibility to disease infestation, rotting e..t.c could place the storability of the healthy ones at risk.

3. **BETTER OR MORE IMPROVED STORAGE STRUCTURES.**

For local and not-too-large storage situations even better structures that could reduce the chances of loss incursion should be considered. Some of them I would suggest be adopted immediately as the storage structures situation is responsible to a large extent for the recorded degrees of loss. These are listed below.

a) STORING TUBERS ON SHELVES MADE OF POLES.

Open-sided shelves (as opposed to local huts and barns available for storage in most parts of the L.G.A's in question) constructed from live poles or bamboo poles, or even sawn wood, should be considered. ~~The diagram below~~ (fig.V) ~~is a pictorial representation of what I have in mind.~~

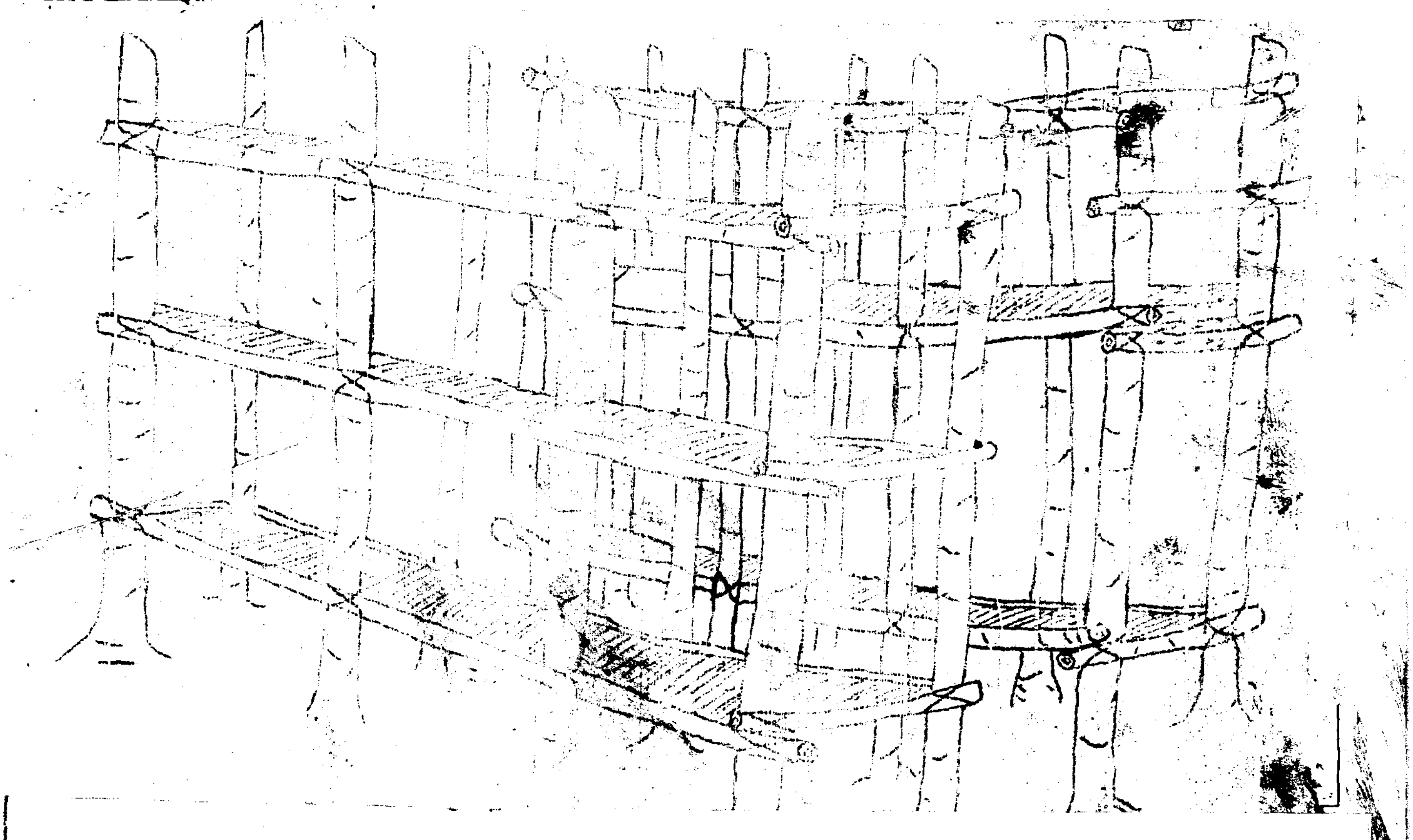

FIG V: ELEVATED PLATFORM OF SHELVES USED IN ROOT AND

The use of shelves enables the tubers to be more carefully handled. The use of ropes to tie yams to poles (as seen in some of the visited L.G.A's) can cause damage to the tubers, and thus initiate rotting. The use of these shelves allows for easy reemoval of tubers which show signs of deterioration and a more careful inspection of the tubers and roots which one is storing.

It also facilitiates air movement within the stored produces, thus, reducing the chances of dampng, owing to over-crowded produces.

b) CONSTRUCTION OF WELL VENTILATED SHED OR BARN OVER THE SHELVES

Most places visited revealed that most farmers are already skilled in the air of constructing local equivalent of Basins as storage structures, however the need to make these Basins more ventilated (more and bigger windows etc.) still arises as the available facilities in most of these areas have the problem of poor aeration resulting from poor ventilation. Improving on this would greatly enhance produce storability.

These well ventilated sheds or barns should as a matter of fact, be constructed over the shelves (fig V) to protect them (the stored roots & tubers) from the direct influence of the whether (eg Rain, Sunlight e.t.c.)

c) ADDITIONAL PROBLEM OF BARNS FROM RODENTS.

The barns thus constructed can be protected from rats and other rodents (mentioned in 4.6). This can be done by fixing a barrier about 1 metre high aroung the barns. The height is important as rats can jump over low barriers. Iron sheets are the most readily available. If the ground is soft, (e.g thee storage sites in most parts of Diko, Gurara L.G.A). The barriers should extend below the surface to prevent rats from digging a way underneath. Alternatively, the sides and ceilings of the barn can be protected with strong wire mesh. Other methods of rat control such as the use of cats, traps or anti-coagulent rodenticides may be required within the barns in cases of heavy rat infestation.

III. ERADICATING SPROUTS.

Normally, after about two months of storage, the tubers especially the yams, will begin to sprout (observation is regular for all stations). The sprouting buds should be manually removed by breaking them off as soon as they appear.

The barns should be inspected at least once a week, thus increasing the frequency of the

5) jute bags for storing, transporting and disinfecting yam chips should not be over-filled, as it ia the practise at present in most of these areas. They should be filled to a level in the bag where they can be properly sewn-up. This present method of filling, pre-disposes the dried yam to heavy insect infestation (as observed in some bags of yam chips transferred from Kaliko to neighbouring Zungeru).

6) As much as possible, the dried yam should be protected from re-wetting by rain or water, as this will raise its moisture content above safe levels for storage, and it will become mouldy. This way, yam chips can be stored for much longer periods.

Another way yam is stored is by milling it into flour and used for food. The flour is stirred vigorously in boiling water to give a mass of good consistency called **'Amala'** (by the Yorubas). The flour is generally not stored for a long period and therefore there is not much problem about its storage. However, itis still needful to take note of some observations made.

5.3.3 STORAGE OF YAM FLOUR.

1) The dried yam chips to be milled should be properly dried to 15% m.c or less, or to levels indicated in 5.4.2 (2), so as to prevent moulding.
2) All stages of development (eggs, larvae, pupae and adult) of the insect pests on such dried yams must be thoroughly destroyed with effective fumigaton before milling.
3) The milled product i.e the flour, should be stored in a thick-guage plastic bag which is sufficiently air-tight and can physically prevent insect re-infestation of flour and moisture uptake. Right now, what most villages use for storage of the flour and chips are simple containers, or at best jute bags, which are insufficient for proper storage.
4) In most cases,since the guage plastic bags are not readily available, the available tins, drums (e.t.c) for storage should prevent moisture and insects from getting into the flour.
5) If all available for storage of yam flour is polythene bags, (as observed in some areas), then the stores must be sufficiently rodent-proof.

5.4 RECOMENDATIONS FOR THE CONTROL OF RATS (RODENTS) IN STORES.

Rodents, (basically rats) could become real storage menaces, as they contribute acutely to certain degrees of product deterioration. As observed in most places, the problem is persisent because of the generally shabby attitude of farmers on their storage sites. The following are recommendations for effectively contending with this problem.

1) GENERAL CLEANLINESS AND PROPER HYGIENE ON STORAGE SITES.

In as much as itis practically impossible to maintain outright order and total sight tidiness, to a great extent however, it ia still possible to maintain a higher degree of site hygiene i.e avoiding unneccesary waste heaps, in and around the barns, avoiding disordered arrangement of tubers e.t.c, as rodents are generally attracted to litter and bins. This way, their incidences can be drastically reduced.

2) INTRODUCTION OF RODENT-GUARDS TO THE STEMS OF THE STORAGE PLATFORMS.

This is taking into consideration the fact that most times, the rodents have to crawl up the stems of the platforms to get to the stored products. Therefore, creating an impediment in their way would mean disallowing, or rather discontinuing their climb.

The impediment in this case is a suggested rodent guard, made up of polished metal or simply a smooth aluminium sheet folded in the form of a cane and attached to each stem of the platform. It impedes the rats' climb as its' cane structure encloses on the rats' upward movement, and its smooth surface offers a slippery base, thus disallowing the rat from climbing. This way, the rats never get to reach the produces. An ilustration of the rodent-guard is shown below in fig.VI

This metod is being successfully used by villages in Diko, after being suggested to them by me.

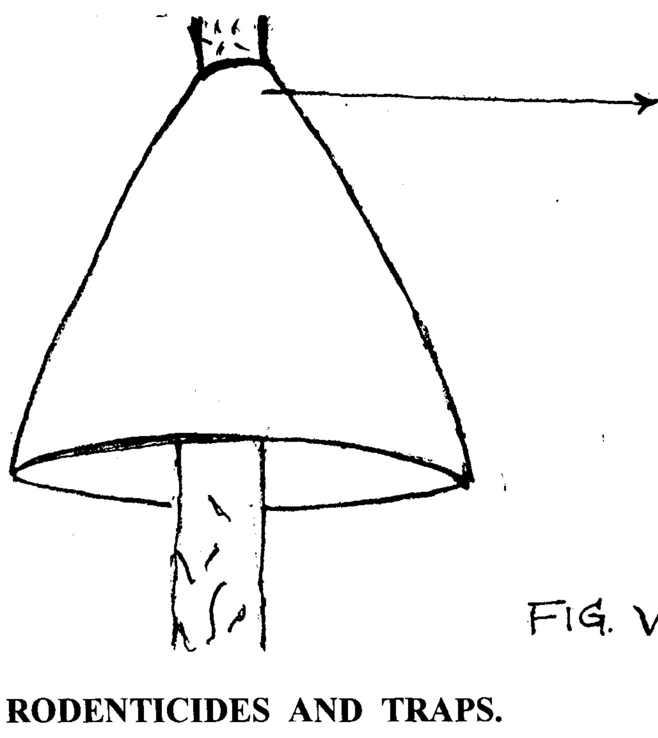

FIG. VI: RODENT GUARD

3) USE OF RODENTICIDES AND TRAPS.

Depending on the levels of infestation, alternatives of traps (in cass where infestation is not heavy) or rodenticides (in cases of heavy infestation) such as 'Racumin', 'Ratak', 'Vacar',

5.5 GENERAL CONCLUSION.

Effective storage of roots and tubers is absolutely necessary, as saving from deterioration or waste what has been harvested, is an essentisl aspect of its production.

Roots and tubers are very important staple food crops as they form a major part of the diet of millions of Nigerians, contributing about 15% of the daily energy requirement (Olayide et al, 1979), therefore no effort aimed at improving the efficiency of their storage is a wasteful one, as it will affect their overall availability to the generality of the Ngerian populace.

REFERENCES

1. Adesuyi, O.A (1977) — Post-Harvest Losses in Tropical Roots and Tubers ; A Review of Tropical Science (I), 152-156 p

2. Adesuyi, O.A (1979) — Post-Harvest Losses in Tropical roots and tubers; A Review of Tropical Science (III) 30-35 p

3. A.D.P, Niger State (1992) — Niger State Agricultural development project programmes; Vol I & II.

4. Ajisegiri, A. (1987) — Personal communication

5. Ajisegiri, A. (1992) — Personal communication

6. Booth, R.H. (1973) — The Post-Harvest Phytopathology of perishable tropical produce; Path 51 (12) 751- 756p

7. Booth, R.H. (1978) — Storage of tropical root crops; PANS manual (12). Centre for overseas pest research, London.

8. Booth, R.H. et al (1978) — Effect of storage temperature on the storage quality of roots and tubers, Bell and Hyman, 1978 16 (3), 111 - 117.

9. Burtan, S.A. (1970) — Storage diseases of Yam. Heinamann Education Books Limited, pp 53.

10. Chukwu, O. (1995) — Notes on Farm buildings and structures, D.A.E., F.U.T., Minna.

11. Caursey, D.G. (1960) — A review of storage diseases of yam (Vol. I), The Maple Press company, N.Y. 66p

12. Caursey, D.G. (1968) — Asphyxiaton; its effect on the central cells of stored produce, The Maple Press company, New York, 32 - 43p.

13. Doku, I.S. (1969) — Storage diseases of stored roots and tubers; N.A.S. series, Vol. I. 66-92p.

14. Ejiofor, M.A.N. et al (1983) New techniques in roots and tuber processing ready for commercialisation, Paper presented at advisory briefing on food processing, Presentation and storage at N.R.C.R.I, Umudike.

15. Ene, L.S.O (1986) Welcome address Proc. 3rd Triennial symposium of the Internatonal society on Topical root crops, PANS manual (4). Centre for Overseas pest research, London.

16. Ene, L.S.O. (1981) Sourcing and processing raw materials for flour bakery and confectionary industries; Paper presented at 1st National Service of Directors of Research Institute, Enugu, Nigeria

17. F.A.O. (1980) Food loss prevention in perishable crops, F.A.O. Agric series, bulletin no. 43, 72p.

18. F.A.O. (1982) Food loss prevention in perishable crops, bulletin no. 49, 67p.

19. Gonzalez, M.A. (1972) Storage of fresh yam under controlled conditions, Journal of Agric, University of Puerto- Rico (56) 46-56p.

20. Gollifer, R. et al (1973) Physiological factors responsible for deterioration of stored potatoes, John Wiley and Sons, New York (52) pp 32-62.

21. I.I.T.A., (1977) Roots and tubers in Nigeria; A reference manual II, Ibadan.

22. I.I.T.A., (1990) Cassava in Tropical Africa; A reference manual, Ibadan.

23. Ingram, A.T. et al Physiological and Pathological factors responsible for the deterioration of stored Cassava; A review of tropical Science 14 (2), 131-148 pp.

24. Iromine, O. (1969) Effect of storage period on the nutritional

25. Jeans, I.S. et al — Yam storage; John Wiley and sons, New York (65) 45-65 pp.

26. Kushman, D.O. et al — The tropical tuber crops; John Wiley and sons, 243pp.

27. N.P.C. (1995) — Niger state population bulletin, 1995.

28. N.R.C.R.I. (1981) — National Root Crops Research Institute, Umudike, Annual Report .

29. Nwodu, E.C. (1983) — Control of post-harvest deterioraton of fresh Sweet potatoes N.R.C.R.I., Umudike, Annual report 145-148pp.

30. Nwodu, E.C. et al (1986) — Control of storage pests of roots and tubers Vol. I, 16-25pp.

31. Olayide, A.O. et al (1979) — Roots and tubers in the West African sub-region Vol. I (33).

32. Oxford A .O. (1984) — Advanced Learners' English Dictionary, 17th Edition.

33. Thompson, O. (1952) — Storage pests of yam, The Maple Press company, New York (52) 24-27pp.

34. Thompson, O. (1973) — Chemicals: Eradicating storage pests of yams, The Maple Press, New York, 64pp.

35. Thompson, O. (1992) — Effects of storage temperature on Yam storage (66) 16-22 pp.

36. Turner, S. (1959) — Controlling decay in stored produces, Manual IV, 6-13pp.

37. Umeh, O. (1987) — Post-harvest losses in developing countries N.A.S. series, 62pp.

38. Wagner et al (1983) — Quonset type storage for roots and tubers (1), Pitman publications, 14-16pp.

39. Wholey, I. (1978) — Tropical Science Vol.II, 40-52 pp.

1. G?A........................

WARD........................

NAME........................ 4. AGE........................

Which crops do you cultivate yearly [ ] yam only [ ] Cassava only [ ] Sweet potatoes [ ] Yam cassava [ ] Yam, cassava &S/Potatoes

How many tubers do you harvest yearly

Yam	[ ] 500-1000	[ ] 1000-1500	[ ] 1500-2000	[ ] over 2000
Casava	[ ] 500 - 1000	[ ] 1000 -1500	[ ] 1500-2000	[ ] Over 2000
Sweet Potatoes	[ ] 500 - 1000	[ ] 1000 -1500	[ ] 1500-2000	[ ] Over 2000

About how many do you sell

Y	[ ] ½	[ ] 1/3	[ ] 1/4	[ ] 1/5	[ ] Others
C	[ ] ½	[ ] 1/3	[ ] 1/4	[ ] 1/5	[ ] Others
S/P	[ ] ½	[ ] 1/3	[ ] 1/4	[ ] 1/5	[ ] Others

Process into other forms

Y	[ ] ½	[ ] 1/3	[ ] 1/4	[ ] 1/5	[ ] Others
E	[ ]	[ ]	[ ]	[ ]	[ ]
S/P	[ ]	[ ]	[ ]	[ ]	[ ]

Store

Y	[ ]	[ ]	[ ]	[ ]	[ ]
C	[ ]	[ ]	[ ]	[ ]	[ ]
S/P	[ ]	[ ]	[ ]	[ ]	[ ]

How do you store freshly Harvested Produces.

Y	[ ] Barns	[ ] Pit	[ ] Handing	[ ] Other method(State)
C	[ ]	[ ]	[ ]	[ ]
S/P	[ ]	[ ]	[ ]	[ ]

Problems before storeage

Yams [ ] Deep cut (High) [ ] Deep cut (medium) [ ] Slight bruises