ESTIMATION OF POSTHARVEST LOSSES OF CASSAVA AND METHOD OF IMPROVING ITS STORAGE (CASE STUDY OF KOGI STATE)

BY

YUSUF FARUK ONIMISI

REG. NO: 2003/17965EA

DEPARTMENT OF AGRICULTURAL AND BIORESOUCES ENGINEERING,

SCHOOL OF ENGINEERING AND ENGINEERING TECHNOLOGY

NOVEMBER 2008

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A PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF AGRICULTURAL AND BIORESOURCES ENGINEERING: SCHOOL OF ENGINEERING AND ENGINEERING TECHNOLOGY IN PARTIAL FULFILMENT OF THE REQUIEMENTS FOR THE AWARD OF BACHELOR DEGREE IN AGRICULTURAL AND BIORESOURCES ENGINEERING (B. ENG)

NOVEMBER 2008

DECLARATION

I hereby declare that this is wholly and solely written by me under the supervision of Mrs. Bosede Orhevba No part of this work has either been wholly or partially presented before for any degree else where. Information hereby obtained from published and unpublished work of other have been dully reference and acknowledged.

..........01.12.08.......... ....01 – 12 – 08..........

FARUK ONIMISI YUSUF **DATE**

CERTIFICATION

This is to certify that this project work has been read and approved as being in accordance with the rules governing presentation of projects in the Federal university of Technology, Minna.

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EXTERNAL EXAMINER **DATE**

(ENGR PROF. G.O. CHUKUMA)

DEDICATION

I dedicate this project work to my able and dynamic caring father. Late Mr. Yusuf Adavuruku Ikujonu and my lovely mother. Mrs. Okehi Yusuf.

ACKNOWLEDGEMENT

Glory be to Allah the primal Originator and sustainer of all creation. whose guidance from His divine massages through prophet Muhammad (S.A.W) led me to the path of true.

I sincerely appreciate the effort of my supervisor. Mrs. Bosede Orhevba. for her time. suggestion and careful scrutiny of this project work you are a supervisor among supervisors. thank you ma.

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Muhammad, Abduljelil, not forgetting Kabiru and Dele and all other family members. I did not forget you it just due to my shot comings please bear with me.

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ABSTRACT

This project report presents a study of estimation of postharvest losses of cassava and method of improving its storage in kogi state. The aim is to know and improve on the losses which come after cassava is harvested and also improve on the storage facilities. The farm land used in this project was selected from ten local governments in Kogi state. The method used includes administering of questionnaires to farmers and individual interview to traders and other cassava users. The result obtained shows that the quantity of cassava that is lost is high and an urgent attention should be given to that area. This is due to lack storage facility, lack of knowledge on how to store the produce especially the fresh cassava and low demand of the produce. The optimum a percentage of cassava losses is 9% which can still be reduced. 9% loss of the produce is not good for the growing population of the country.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Cassava

Cassava (*Manihot esculenta*) is a perennial plant. Apart from 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.

Plate 1: Cassava roots

Cassava is a plant of tropical lowland. Its cultivation is restricted to regions between the latitude of 30^0 North and 30^0 South. It is most widespread near the equator between 15^0 North and South. Cassava finds the most favourable growing conditions in humid-warm climates at temperatures between 25 to 29°C and precipitation between 1000 to 1500mm which ideally should be evenly distributed (Onwueme, 1978). In view of the climate, cassava has an enormous ability to adapt. There are locations where cassava is cultivated at an altitude of 2000 meters. Cassava can even survive slight frosts although the plant then loses its leave, which grows again when temperatures rise. Where there are high temperatures 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 likes light, sandy loam soils with medium soil fertility and with good drainage. Saline, strongly alkaline, stony soil and soil 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.

Economically, the most important part of the cassava is the tuber-like thick root which develops from thin roots which takes the nutrients out of the soil. The thick root is connected to the plant by a short, wooden neck. It has a longish round form and can grow between 15 and 100cm and reach a weight of 0.5 to 2.0kg. Cassava root consists of three layers, the cork, perineum and the cortex; below this form the exterior protection for the root. Both cell layers are only a few millimeters 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 length wise. There are cells which can secrete latex in the storage tissue as well as in the cortex. The thick root in a fresh condition contains approximately 62% water, 35% carbohydrates (mainly in the form of starch), 1 – 2% proteins, 0.3% fats, 1 – 2% fibres and 1% minerals.

Plate 2: Cassava plants

Cassava is believed to have come originally from South America, Brazil to be specific. It 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 such as bananas in East Africa and maize and sorghum in the southern parts (Lynam, 1991). Cassava is a widely cultivated staple crop in the tropics (Oyenuga, 1968) wherein Nigeria is located. According to FAO world food perspective report submitted in PANA, it was stated that Nigeria is leading the other African countries by producing 26.0 million tuber tones out of the continent's 72.7 million tuber tones and world's figure of 158.1 million tuber tones of cassava.

Cassava has a potential tuber yield of 70 tones 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 acidic 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 approximately 120 days (manual phase) can be estimated (Cock, 1985). This corresponds to about one quarter of the work input of yams. Production input, e.g. fertilizers, plant protection and propagation, is very low. Fertilizers 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 causes crop failure for other plants.

(*Manihot esculenta*) is the fourth most important source of food energy in the tropics. More than two – thirds of the total production of this crop is used as food for humans, with lesser amounts being used for animal feed and industrial purposes. The crop has a high yield potential under good conditions and compared to other crops, it excels under suboptimal conditions, thus offering the possibility of using marginal land to increase total agricultural production.

1.2 Aims

The aim of this project work is to investigate the post – harvest losses in cassava and methods of improving its storage. In order to achieve the above stated aim, the following objectives must be considered;

1 – Estimation of the quantity of cassava lost after harvest.

2 – Investigation and evaluation of the different storage methods and ways to improve them.

3 – Suggestion given as to how best to minimize the losses.

4– Finally, a conclusion would be drawn on the storage structure or method which can best suit a particular area.

1.3 Justification

The high post – harvest losses in cassava and low storage quality of the produce calls for urgent attention which is the major focus of this project. These losses limit the availability as regard to its market value and scarcity of the produce. Over the years, different causes of storage and other post – harvest losses in cassava have been identified. For this reason, it is necessary and advantageous to ascertain the right storage atmosphere that will minimize or eliminate these losses often encountered in cassava. However, there is need to continue to examine present techniques and strategies with a view to identifying problem area and suggesting possible solution to them. In this lies the justification of this project.

1.4 Scope of Study

This work is limited to the estimation of postharvest losses of cassava roots, and method of improving its storage with Kogi state as case study. 10 Local Government Areas out of the 21 Local Government Areas of Kogi state were considered; these include Kogi, Kabba-Bunu, Lokoja, Olamaboro, Idah, Odolu, Ankpa, Okehi, Adavi, and Ogori-magongo Local Government Areas. This project covers only the losses and storage of cassava and consideration for 2007/2008 harvest seasons. The method of evaluation comprises of personal inspection, distribution of questionnaires.

CHAPTER TWO

2.0 LITRATURE REVIEW

2.1 The Cassava Plant

The cassava plant *(Manihot esculenta* Crantz) is a perennial shrub, ranging in height from one to five meters, with branching stems, green, pale or dark grey or brown in colour. The root crop is an ideal subsistence crop for the tropical world because it is well adapted to marginal soils, has the ability to tolerate environmental stress, gives relatively high yields compared to other staple crops, is an excellent source of carbohydrate and can be kept underground from 6 - 36 months after planting and is thus always available to the farmer. Cassava leaves contain about 7 -12% protein and are used as a vegetable in traditional soups and stews. The root itself is rich in carbohydrates *(32%)*, vitamin C and calcium but poor in protein and other vitamins and minerals. Cassava roots are different from yams because they are not dormant organs and thus have very few biological functions.

Plate 3: Cassava plantation

2.1.1 Varieties of Cassava

It had been suggested that before modern research on cassava started in Nigeria in 1954 at the FDRA, Ibadan, there were numerous local ecotypes of traditional clones. These varied in their tuber yield and general tolerance of prevailing pest and disease. *Oloronto* (53101), a local cultivar from the Ibadan/Abeokuta area, was then recommended for southwestern Nigeria. It was later used in crosses in 1967 which led to the release of improved varieties such as 60444, 60447 and 60506 for whole country.

In 1972 when cassava bacteria blight (CBB) become a scourge for cassava in the country, only 60303 and a few local types tolerated the disease. Breeding work at IITA later identified improved clones which where released after 1976. Releases of first two IITA clones namely TMS 30211 and TMS 30395 were rapidly followed by TMS 30572 TMS 30001, TMS 300017, TMS 30110, TMS 30337, TMS 30555, TMS 4(2)1425 and others (IITA 1984).

These improved varieties differed in their resistance to cassava diseases and pests such as CBB, Cassava mosaic virus (CMV), cassava anthracnose disease (CAD), cassava mealy bug (CMB) and cassava green spider mite (CGM). They also produced tubers with varying quality of roots at different maturity duration and storage in the ground. These improved varieties always gave high yields (Okigbo, 1978; Hahn, 1983; Herren and Bennett, 1984; IITA 1984 and Otoo and Hahn, 1987). Farmers preferred improved varieties because of their higher yields, earlier maturity, high suppression of weed, and d greater resistance to diverse diseases and pests (Akoroda et al1985; 1987, Ikpi et al 1986).

A wild range variety of cassava cultivars can now be observed in farmers' fields but one or two cultivars may occur more frequently in a given zone. Thus, the most commonly observed local cultivars in south-west and middle belt of Nigeria are:

(a) "*Odongbo*" with its reddish petiole, cream-colored stem, moderate branching, and clear while flesh.

(b) "*Oyarugba dudu*" with indeterminate growth habit, whose origin is suspected to be from IITA; s stock dispersed by some extension staff in the 1970s, and

(c) "*Isunikankiyan*" a high-branching, erect cassava variety with reddish petiole, stem and pieriderm, usually early maturing mealy and sweet.

Normally, a field of cassava in south- west Nigeria may contain different combinations of all four varieties including some other minor cultivars. However, the most commonly grown local variety in south-western Nigeria is *odongbo* which bears different names in different parts of Nigeria e.g. *Jejeti* in Warri, Delta state.

2.1.2 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 the region. Cassava finds the most favourable growing conditions in humid-warm climates at temperatures between 25 to 29°C and precipitations of between 1000 to1500mm which ideally should be evenly distributed (Onwueme, 1978).

In view of climate, cassava has an enormous ability to adapt. There are locations in the Andes where cassava is cultivated at an altitude of 2000 meters. Cassava can even survive slight frosts although the plant then loses its leaves which grow again when temperatures rise. Where there 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).

2.1.3 The Production of Cassava (World, Africa and Nigeria.)

In the tropics, cassava is the most important root crop and as a source of calories for human consumption it ranks fourth after rice, sugar cane and maize. It is a major carbohydrate food for an estimated 500 million people and in tropical Africa it is the single most important source of calories in the diet (CIAT, 1992). The roots are the principle edible portion of the plant and typical ranges of composition given are; water 62 to 65 percent, total carbohydrate 32 to 35 percent, protein 0.7 to 2.6 percent, fat 0.2 to 0.5 percent, fiber 0.8 to 1.3 percent and ash 0.3 to 1.3 percent (Kay, 1987). In nutritional terms, cassava is considered primarily as a source of carbohydrate energy, most of which is derived from starch. Total world production has increased from 70 million tonnes in 1960 to an estimated 150 million tonnes in 1990 (Table 1). Of this total, 43 percent is produced in Africa, 35 percent in Asia and 22 percent in Latin America. In the Americas during the 1970s and early 1980s there was a decreasing trend in cassava production which, since the late 1980s, has gradually changed into one of slow growth. During the period from 1985 to 1990 cassava production increased by 9.6 percent, from 29.6 million tonnes to 33.7 million tonnes (FAO Yearbooks). Brazil, Paraguay and Colombia, which together represent 92 percent of total cassava production on the continent, have all experienced growth in production.

Cassava production in Asia has risen, almost 1.5 percent above the annual population growth rate, from 48.5 million tonnes in 1985 to 52.0 million tonnes in 1990. The two major Asian cassava-growing countries, Thailand and Indonesia, have shown the largest increases in production. The Thai cassava industry was for several years largely based on the export of cassava pellets to the European Union (EU). Despite the introduction of quotas by the EU during the mid-1980s, which threatened to limit growth in this market, Thailand's comparative advantages have kept the cassava industry buoyant and other export markets in Asia, Eastern Europe and the Russian Federation have been developed. Thai cassava exports have continued to experience an annual growth rate of 7 percent from 1985 to 1990. Although export volumes from Indonesia are only one-tenth of those from Thailand, the former has experienced an even stronger growth (17.1 percent) during this period. During the period 1985 to 1990 increases occurred in cassava starch production and in Japan investments have been made into plants for producing modified cassava starch and other starch derived products (CIAT, 1992). The apparent decline in cassava production in the People's Republic of China (Table 1) is not substantiated by local figures, which report a significant increase (CIAT, 1992). Cassava production in Africa increased from 58.2 million tonnes in 1985 to 64.1 million tonnes in 1990, a growth rate of 2 percent per annum. The most significant increase in production was recorded by Uganda, with a growth rate of 6.3 percent per annum. In Nigeria the ban on wheat imports provided a stimulus to cassava production, which rose from 13.5 million tonnes in 1985 to 17.6 million tonnes in 1990.

TABLE 1.1: World, Africa and Nigeria cassava production (in million tonnes)

	1985	1986	1987	1988	1989	1990	Annual growth Rate (%)
World	136.6	133.6	136.8	141.3	148.6	150.0	2.34
Africa	58.2	58.6	58.4	59.6	62.9	64.1	2.04
Nigeria	13.5	14.7	14.0	15.0	16.5	17.6	4.97

Source: FAO Production Yearbooks. Notes: Figures are approximations.

2.2 Importance of Cassava

No continent depends as much on root and tuber crops in feeding its population as does Africa. Cassava *(Manihot esculenta)*, yams *(Dioscorea sp.)* and sweet potatoes *(Ipomea batatas)* are important sources of food in the tropics. The importance of cassava to many Africans is epitomized in the Ewe name for the plant, *Agble*, meaning "there is life". The production trend world-wide is positive for cassava over the last years, and the production increased by 12.5% between 1988 and 1990 with Nigeria becoming the largest Cassava producer in the world. Cassava occupies an important position in Nigeria's agricultural economy and contributes about 46% of the agricultural Gross Domestic Product *(GDP)*. Cassava accounts for a daily calorie intake of 30% in Nigeria and is grown by nearly every farming family in large part of the country such as the north-central-south-west, south-south and south-east part of Nigeria. Cassava is the most favoured among all root crops and even all food crops by Nigerian consumers.

Cassava is the fourth most important source of food energy in the tropics. More than two-thirds of the total production of this crop is used as food for humans, with lesser amounts being used for animal feed and industrial purposes. The ingestion of high level of cassava has been associated with chronic cyanide toxicity in parts of Africa, but this appears to be related to inadequate processing of the root and poor overall nutrition. Although cassava is not a complete food, it is important as a cheap source of calories. The crop has a high yield potential under good conditions, and compared to other crops it excels under suboptimal condition, thus offering the possibility of using marginal land to increase total agricultural production. Breeding programs that bring together germ plasm from different regions coupled with improved agronomic practices can markedly increase yields. The future demand for fresh cassava may depend on improved storage methods. The markets for cassava as a substitute for cereal flours in bakery products and as an energy source in animal feed rations are likely to expand. The use of cassava as a source of ethanol for fuel depends on finding an efficient source of energy for separating ethanol from water.

2.2.1 Nutritional Content of Cassava

Onwueme, (1977) reported that the thick root in a fresh condition contains approximately 62% water, 35% carbohydrates (mainly in the form of starch), 1 to 2% proteins, 0.3% fats, 1 to 2% fibers and 1% minerals (ONWUEME, 1977). In comparison to the yam tuber, the cassava root contains more energy but far less protein.

2.2.2 Cassava Products and Its Uses

In Nigeria, cassava has different product and uses to different people so also Africa and the rest of the world. Some product of cassava and their uses are stated below: *Gari, Fufu,* High quality cassava flour, Tapioca, Ethanol from cassava, Animal feed and Starch production

Gari: Gari is creamy white, granular flour with a slightly sour taste made from fermented gelatinize fresh cassava tubers. *Gari* is widely known in Nigeria and other African countries. It is commonly consumed either by being soaked in cold water with sugar, coconut, roasted groundnut, dry fish, or boiled cowpea as compliments or as past made with hot water and eaten with vegetable source. When properly stored, it has a shelf life of six months or more.

Plate 4: ***gari***

FUFU: Fufu is a fermented wet-paste made from cassava. It is ranked next to *gari* as an indigenous food of most Nigerians in cut peeled cassava roots in water to ferment for a maximum of three days, depending on ambient temperature. During steeping, fermentation decreases the pH, softens the roots, and helps to reduce potentially toxic cyanoganic compounds. When sufficiently soft, the roots are taken out, broken by hand, and sieved to remove the fibers. At present, processors sieve manually by adding water to the retted mass on nylon or cloth screens. The fiber produced as a by-product is sold for animal feed, either in its wet form or after sun drying. The sieved mass is allowed to sediment in a large container for about 24 hours. After sedimentation, the water is poured off while the fine, clean sediment (mainly starch) is dewatered using a high powered press. The cake is then sifted before drying.

Apart from being easy to prepare the consumable form, dried *fufu* has the advantages of having a longer shelf life, being more convenient to store, and less bulky. When cooked, *fufu* is a creamy/white smooth textured product. When properly packaged and stored, dried *fufu* flour has a shelf-life of six months or more.

Cassava Flour: This is a simple unfermented cassava flour. The IITA production process minimizes the capital investment requirements for flour production by making use of simple equipment already used for *gari* processing. Under optimal conditions (dry sunny weather for sun drying), the IITA technique enables small-scale primary processors to produce high quality unfermented cassava flour that meets the specifications of industrial users within one day. Drying has been identified as the major tool for expanding processing of cassava into high quality cassava flour. Various options have been considered so far in the cassava project at IITA.

Tapioca: Tapioca meal is made from partly gelatinized cassava starch through the application of heat treatment to moist mash in shallow pans when heated, the wet granules gelatinize, burst, and stick together. The mass is stirred to prevent scorching. It is manufactured in the form of irregular lumps called grits or in perfectly round beads. The grits are made into a grained product by milling gelatinized lumps and sifting. Tapioca is consumed in many parts of West Africa. It is usually soaked or cooked in water; sugar and milk are added.

Ethanol from Cassava: Ethanol is generally produced by the fermentation of sugar, cellulose, or converted starch and has a long history. In Nigeria, local production of ethanol from maize, guinea corn, millet, other starchy substrates, and cellulose is as old as the country itself. Apart from food and pharmaceutical uses, ethanol is finding itself alternative use for biofuel in most of the developed world for the following reasons: it is not poisonous, it does not cause air pollution or any environmental hazard, it does not contribute the greenhouse effect problem ($CO2$ addition to the atmosphere, causing global warming), it has a higher octane rating than petrol as a fuel. That is, ethanol is an octane booster and anti-knocking agent, it is an excellent material for synthetic chemicals, ethanol provides jobs and economic development in rural areas, ethanol reduces country's dependence on petroleum and it is a source of non-oil revenue for any producing country and finally ethanol is capable of reducing the adverse foreign trade balance.

Livestock Feed Formulations with Cassava: Cassava flour can be complimented with a large number of ingredients that provide the nutrients needed to obtain balanced food rations for poultry. Soybean (full fat) is presented as a very special and synergetic resource in the design of programs with high nutritional quality. The lack of protein and essential fatty acids that characterize the cassava flour can be amply satisfied with the use of soybean. Indeed, a balanced mixture of cassava flour and whole soybean can totally meet the requirements of energy, protein, and essential fatty acids for broilers and layers.

Cassava Starch Production: Starch is one of the most abundant substances in nature, a renewable and almost unlimited resource. Starch is mainly used as food, but is also readily converted chemically, physically, and biologically into many useful products to date. starch is used to produce such diverse products as food, paper, textiles, adhesives, beverages, confectionery, pharmaceuticals, and building materials. Cassava starch has many remarkable characteristics, including high paste viscosity, high paste clarity, and high freeze-thaw stability, which are advantageous to many industries. Cassava starch is produced primarily by the wet milling of fresh cassava roots but in some countries such as Thailand, it is produced from dry cassava chips. Starch is the main constituent of cassava. About 25% starch may be obtained from mature, good quality tubers. About 60% starch maybe obtained from dry cassava chips and about 10% dry pulp may be obtained per 100kg of cassava roots. For cassava, the process of starch extraction is relatively simples as there are only small amounts of secondary substances, such as protein, in the roots. When cassava roots are harvested or selected for starch extraction, age and root quality are critical factors.

2.4 Storage

The greatest problem facing the human race is that of feeding due to expanding population. Man's dependency on plant for survival have been of paramount importance because he, at any particular time should be able to provide foods for his immediate family which can last him for a particular period of time before he start looking for another. This implies that crop is of great importance to the existence of mankind but the man today has larger use or need for the crops grown by him to satisfy his various wants, this leads to the storage of produce gotten from small, medium or large scale farmers. Storage as defined by Ajisegiri (1987) is the setting aside for future use of separable items.

2.4.1 Storage of Fresh Cassava

The starch-storing root of cassava is of no importance for vegetative propagation. This means that the cassava, in contrast to 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 to 3 days at the harvest. This means a high selling risk for the seller as the produce becomes unsalable after a short time.

2.4.1.1 Storage of Fresh 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. With this method of storage, the rhythm of the harvest can be adapted to that of consumption. Lancaster and Coursey (1984) reported that the root losses more and more substance, particularly starch, the constituent which defines its value, the longer storage is. Also the root begins to become woody and impairments to the flavor occur. During storage in the soil there is also 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 area, 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.

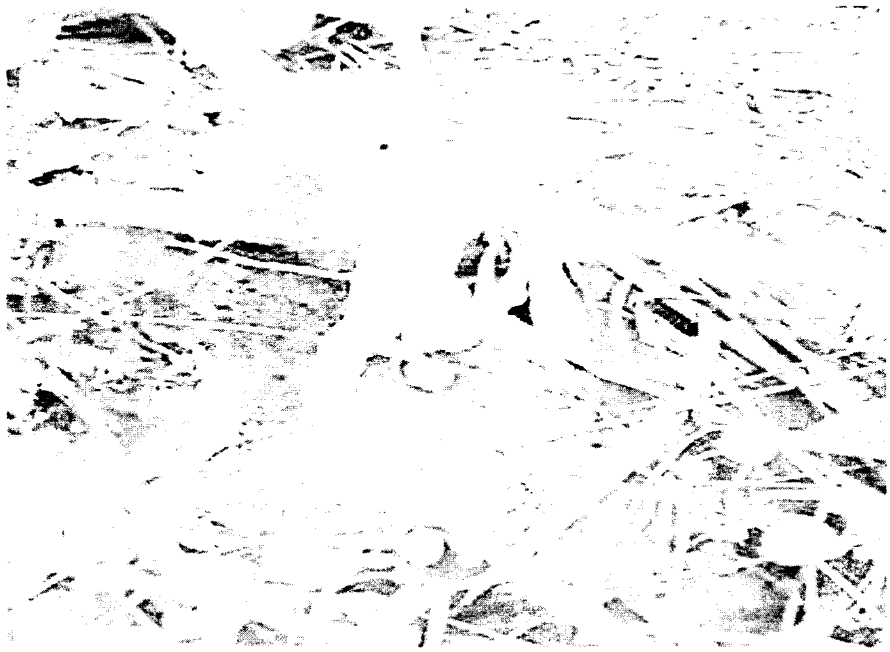

Plate 5: Matured unharvested cassava

2.4.1.2 Traditional Methods of Storing Fresh Cassava Roots

Fresh harvested roots can be buried in the soil to preserve them. This method is evidently oriented to the process of leaving ripe cassava roots unharnessed 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 (Rickard 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 to 6 days (Rickard and Coursey, 1981).

In order reports on traditional storage methods processed 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 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 favorable picture.

2.4.1.3 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 Centro International de Agricultural 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 500kg 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 el la, 1978). What remains completely open is whether the storage duration of 4 weeks reached corresponds to the requirements of the farmers.

2.4.1.4 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 deteriorated 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 to 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, they were subjected to three days of curing. Storage periods in Ghana using this method reached two months (injured and cured roots) and up to six 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 which saves on handling costs and also reduces injury to the roots during transport.

2.4.1.5 Storing Fresh Cassava Roots in a Dip

Storing fresh cassava root 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 dealer are mostly already 1-2 days old, the storage ability of the root is hardly improved by this method. The limited extension of storage is not the sole criterion for the selection of this method. This process is far more a method of simultaneously detoxifying the root which contains hydrogen cyanide.

2.4.1.6 Storing Fresh Cassava Root in Plastic Bags

The use of plastic bags to preserve cassava roots can be seen as a consistent extension of traditional storage method which serves 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 reduce 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 Colombia 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 cans 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 is consideration differences between the living and eating habits. In addition, it must be determined whether the consumer is willing to bear the extra cost involved in storage.

2.4.1.7 Uses of Modern Method to Store Fresh Cassava Root

The modern methods of storage involved here comprise refrigeration and freezing, waxing of the root and chemical storage protection. Reduced temperatures extend the storage ability of cassava root by delaying the rot processes which occur rapidly at normal storage temperature. Experiments have shown that the most favorable temperature for the storage of fresh cassava root 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 occured on the surface of the root at higher storage temperature and the flash of the root turned brownish. Both caused 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 flavor is preserved (Rickard 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 preservations 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 Colombia, fresh cassava roots were simple 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. Whether the storage ability is improved by the fungicide or whether this is due to the wax coating reducing respiration and the supply of oxygen has not finally been investigated.

2.4.2 Preparation of 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 the maximum period of storage may be attained. It must be made sure that 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 more serious injuries occur at the roots 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 Humphris, 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 (Rickrd and Coursey, 1981).

2.4.3 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, vary 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 before, 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). For farmers who have attained a cretin 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 can still be included in the fields of storage and post-harvest technology.

2.4.4 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 undergoes structural changes (Plumbley and Rickard, 1991). Experiments have shown that no microorganisms are involved in the change of colour. This is based on an endogenous oxidative process. The colouring can be delayed by cutting of 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. Considered economically, primary deteriorations is more significant than secondary deterioration. Discolouration parallel to primary deterioration causes a distinct decline in the value on 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.

2.4.5 Storage of Dry Cassava Roots

The purpose of processing cassava root into a wide range of products is to control the deterioration of the food products, in this, drying of cassava roots come to play. There are several way of storing dry cassava roots depending on the area and the people of the area.

2.4.5.1 Storage of Dry Cassava Roots in Sack

Dry cassava root or chips are stored by packaging it in sack. The sack of cassava chips (dried) are then taken to a room or a conducive atmosphere free of damage. This type of storage can take eight to ten month.

2.4.5.2 Storage in traditional *Kanbon*

The construction of a traditional *Kanbon* consists of a cylindrical basket built on a wooden or stone platform or stand which is only slightly raised 0.2 m above the ground. The basket is made of grass mats *(zanamats)* and varies in size. The basket can be between 1 - 2 m high and 1.5 - 2.5 m in diameter. The traditional *Kanbon* is covered with a grass thatched lid which is normally removable and serves as an inlet and outlet for cassava chips. In many cases, a small grass door in the basket is used for the same purpose. The inside of a *Kanbon* can be plastered with a mud cover or cow dung. The cassava chips are loosely arranged in the basket. The life span of such a structure varies, according to farmers, from three to five years.

2.4.5.3 Storage in Improved *Kanbon*

The improved version of the *Kanbon* is constructed in the same way as described above for the traditional version but the basket is raised well above the ground, approximately 0.5 to

1.1 m, on a wooden platform which allows for ventilation underneath. The poles can be made rodent-proof with metal sheets. The basket of an improved *Kanbon* varies in diameter from 1.5 to 2.5 m. The life span is estimated by farmers to be two to six years. The basket is sometimes coated with mud or cow dung on both the inside and outside.

2.4.5.4 Storage in *Napogu*

This type of cylindrical store is the longer-lasting one and has a mud base covered by a thin layer of cement. It usually has a conical grass roof with an access hole just below it. Provided the foundation does not subside and crack, its life is considerably longer than that of the traditional woven basket stores. This construction consists of a cylindrical mud house and is covered by a thatched roof. Inside the structure there is commonly a wooden platform covered with *zanamats* on which chips are loosely arranged, and underneath there is space where fowl find shade or belongings are stored. The height of a *Napogu* varies considerably and is usually between 2 and 2.5 m without roofing. The diameter is between 2.5 and 3.5 m, and the life span of a *Napogu* is estimated by farmers between five and twelve years.

2.4.6 Storage Techniques

According to *MOFA-GTZ (1994)* treatment of dried cassava chips is rarely performed, and only about 3% of farmers claim to use chemicals, e.g. PHOSTOXIN (Aluminium phosphide) tablets. The only recommendation given by the extension service is the use of Actellic 50 or 100 (Pirimiphos-methyl); however, the extension service has not received any practical training on proper storage of chips. They also reported that experience with protection measurements for cassava chips from the research side is also lacking. The information on protection of maize produce is simply transferred to cassava. In most cases, the farmers perform sanitation and dry the cassava chips properly before storage. But some farmers observed that excessive drying of chips may even increase the possibility of insect attack, whereas less-dried chips are prone to mould infestation. During the storage period, farmers check their produce regularly and remove it for further sun-drying when heavy infestation is visible.

2.5. Postharvest Losses of Cassava

The rapid post-harvest deterioration of cassava restricts the storage potential of the fresh root to a few days. In addition to direct physical loss of the crop, postharvest deterioration causes a reduction in root quality, which leads to price discounts and contributes to economic losses.

2.5.1 Physical post-harvest loss

Although rapid deterioration of freshly harvested cassava is considered an important factor in postharvest studies, little reliable information is available on loss figures. In some documents these figures seem to be only gross estimates based on anecdotal evidence and frequently the terms waste and loss are used without clear distinction. The term loss will be used throughout this chapter since waste can be considered a voluntary disposal of unwanted material such as peel. Widely differing levels of post-harvest losses have been obtained in studies on cassava production and use in Asia conducted by CIAT in collaboration with national programmes (CIAT, 1987). The loss figures given were generally established on a macrolevel and do not indicate the cause of loss. The loss figure estimates were in the range of 10 to 12 percent in India (Kerala and Tamil Nadu States), 5.3 percent for the whole of Indonesia, 6.2 percent for Java and 3 percent elsewhere. In Indonesia, however, component losses were assessed as 8 percent for marketed cassava and 15 percent for *gaplek* (large pieces of dried cassava). Loss estimates for China based on FAO figures, which have been used for every year from 1961 to 1983, are 3 percent. The only figures available for Thailand (the world's leading exporter of cassava products) are for the exports of cassava products for animal feed; for Malaysia no loss figures are available. In the Philippines loss and animal feed figures are reported together.

A survey of consumer purchasing habits of fresh cassava and other starchy staples, undertaken in the Atlantic coast region of Colombia (CIAT, 1983), provided the following loss estimate figures: metropolitan urban areas 15 percent, intermediate urban areas 5 percent and rural areas 5 percent. Another simultaneous survey of market agents in the same area showed that deterioration accounted for 14 percent of the costs of the total marketing margin. A study on cassava commercialization in Paraguay in 1987 showed that during marketing about 15 percent of the roots were affected by deterioration, but only about 0.5 percent were completely lost (Cassava Newsletter, 1991). FAO data for 1985 estimate that post-harvest loss for all root crops in Ghana are of the order of 15 to 30 percent and that post-harvest loss of cassava in the Côte d'Ivoire is 27 percent. However, a recent- survey in Ghana indicated low levels of physical post-harvest loss of cassava and estimated losses unlikely to exceed 5 percent (Rickard, Wheatley and Gilling, 1992). The above figures focus on physical post-harvest losses which represent a direct financial loss to the producer, trader, processor or consumer. National loss figures usually do not indicate at which stage of the marketing chain the losses occurred. In addition, available data often do not differentiate between post-harvest deterioration of fresh roots and loss of processed products. The exact value of the loss is therefore difficult to calculate.

2.5.2 Qualitative Post-Harvest Loss

According to studies carried out in West Africa, post-harvest deterioration of cassava causes a reduction in root quality which can result in roots being sold at a discount price. Two cases of discount have been distinguished. A lower price is commanded by old cassava in comparison to fresh roots and a price difference exists between fresh roots and cassava sold in a processed form at a lower price (e.g. fermented or dried). It is often difficult to distinguish between the two kinds of qualitative loss since old roots can be sold both for direct consumption and for processing. The discount depends on factors such as post-harvest age, seasonality, cassava variety, supply and demand of fresh and processed cassava and storage facilities.

It has been suggested that the financial post-harvest loss due to quality price reductions is greater than that caused by physical loss. However, it is difficult to estimate the amount of cassava that is sold at a lower price (Rickard, Wheatley and Gilling, 1992). Discounts commanded by old cassava roots can vary in markets according to location of the market and position of the intermediary within the marketing chain. Cassava which has visible signs of deterioration is not used for *fufu* production but is hand-peeled, chipped and sun-dried to produce *cassava chips*. Although this is a time-consuming and arduous process the price of *cassava chips* is low compared to fresh cassava.

Post-harvest loss is a major risk factor in the production of cassava (NRI, 1992; COSCA Phase 1). Thus, although there are many positive factors that make cassava a well-adapted crop for small-scale agriculture in developing countries, rapid post-harvest deterioration of the fresh roots is a disadvantage that the farmers have to take into account. However, the rapid post-harvest perishability of cassava might be a major factor leading to comparative advantages for small-scale production linked to small-scale processing units. Traditional approaches to rapid post-harvest deterioration have been developed by producers. A common way of avoiding loss is to leave the roots in the soil past the period of optimal root development, until they can be immediately consumed, processed or marketed. The disadvantages of this practice are that land is occupied and thus unavailable for further agricultural production (opportunity cost of land), roots lose some of their starch content, palatability declines as roots become more fibrous (Rickard and Coursey, 1981) and cooking times increase (Wheatley and Gomez, 1985). In Africa, there also exist a number of traditional systems involving cassava storage in pits or clamps. The use of these rudimentary techniques is not widespread as they are considered rather labour intensive and are not always entirely effective. Storage of cassava roots under moist conditions, as encountered in soil reburial methods, can promote the healing of wounds in roots damaged at harvest.

2.5.3 Implications for processing

Avoidance of rapid post-harvest deterioration and reduction of cyanide levels are traditionally the main reasons for processing cassava into different food products. As almost every cassava-growing region in the world has developed its own traditional products there are a large number of foodstuffs based on cassava. Results of the COSCA Phase I survey in Africa show that sweet cassava varieties and non-bitter varieties are more commonly grown and used for processing (NRI, 1992).

Traditional technologies are well adapted to processing cassava into a number of final products characterized by extended shelf-life (Miche, 1984). Traditional processing methods are often very time-consuming and laborious; this is especially the case in Africa where the roots are processed into local products such as *gari*. Cassava starch is produced for both human consumption and industrial use. In Latin America the cassava starch industry is reported to experience several limitations, including low availability of fresh roots, lack of capital, difficult access to credit, poor management and poor starch extraction efficiency (Chuzel, 1991).

The sedimentation of starch from deteriorating cassava is considered by processors in Latin America to be less efficient than from fresh roots. These observations have not been substantiated by reported technical studies but recent results from CIAT (F. Alverez, private communication) have shown that starch extraction rates were significantly affected by post-harvest deterioration. The possible influence of deterioration on starch production is of importance considering the significant role of starch in the cassava economy of a country such as Indonesia. In 1978 about one-third of all the cassava utilized in Indonesia went into starch production (CIAT, 1987). In Thailand the cassava industry experienced a pattern of growth in marked contrast to that of other agricultural commodities, especially the grains. To avoid losses from root deterioration, cassava has to be processed very close to the production areas and processors have to ensure a daily supply of raw material. In the case of cassava the expansion in root production and processing has been based on linking small-scale producers to relatively small-scale processing capacity. Decentralized, small-scale processing was an important strategy to resolve the problem of minimizing transport costs and to avoid postharvest deterioration of a bulky, low value raw material (CIAT, 1987). Fresh roots are generally processed on the day they arrive at the factory and it is rare to find industries that have storage facilities (Thanh, 1974).

Cassava processing industries that use dried raw material, such as *gaplek* for chip or pellet production, do not depend on rapid processing of the roots since the dried raw material can be stored for several months. Seasonal supply shortages of cassava can be avoided by drying peeled pieces of roots immediately after harvest and storing them on-farm or at the site of the processing industry until required (Falcon *et al.*, 1984). In Indonesia, although cassava production does not require large labour inputs, it does generate significant employment in processing and distribution. Similar observations have been made in Viet Nam, where income was higher in villages with small-scale cassava and other root crops industries compared to villages without these industries (Bottema and Henry, 1991).

2.5.4 Implications for Consumption

Cassava is one of the major subsistence crops produced in developing countries. In rural areas of more cassava growing countries the roots are mostly consumed fresh. As cassava harvesting can be staggered, rapid postharvest deterioration does not severely influence on-farm or village consumption. In urban areas, unless motivated by economic considerations, consumers will not generally purchase old cassava roots (three to four days after harvest) as they are assumed to have deteriorated. To demonstrate the freshness of the produce retailers often take extreme measures. In Colombia, root freshness is demonstrated by cutting the roots to show undeteriorated internal tissue. In markets in Ghana it has been observed that market sellers deliberately wound certain parts of the roots to cause latex exudation which is produced only by fresh cassava. Both these activities severely reduce the storage potential of the damaged roots but allow retailers to demonstrate that their produce is fresh.

Cassava roots that exhibit visible symptoms of physiological deterioration are considered to have poor eating and processing quality. Although no survey work has been undertaken on this topic, the following observations have been made regarding cassava that has developed physiological deterioration (Rickard, Wheatley and Gilling, 1992; C.C. Wheatley, private communications):

- it takes longer to cook, has an unpleasant bitter flavour and an unattractive off colour;
- *fufu* processed in Ghana from deteriorating roots has a lower and less desirable elasticity than *fufu* prepared from fresh roots;
- cooked roots are difficult to pound;
- *gari* processed from deteriorating roots has lower and less desirable swelling properties than *gari* produced from fresh roots.

Table 2.1: Strategies to Prevent Rapid Post-Harvest Deterioration of Cassava Roots.

Channel members	Strategies against post-harvest deterioration of cassava
Farmers	• Delay harvest;
	• Traditional storage;
	• Processing of roots into storable products;
	• Processing of old unsold roots.
Traders	• Low quantities traded;
	• High margins to compensate for risk;
	• Buy standing crops;
	• Highly integrated markets;
	• Storage techniques (including traditional techniques and transfe technology);
	• Processing of old unsold roots.
Processors	• Production and processing are in close proximity;
	• Small-scale processing in rural areas;
	• Processing into broad range of products (deed, fermented flours, sta etc. for human consumption, industrial use and animal feed)
	• Production for new export markets (e.g. Thailand).
Consumers	• Substitute fresh cassava with processed foods and cereals unless ch fresh roots are readily available;
	• Improved storage techniques, such as refrigeration.

Source:(CIAT,1988)

Producers, traders, processors and consumers have all developed strategies, as outlined in the Table, to prevent post-harvest losses of cassava. However, quantitative and qualitative loss estimates can often still be high. The production advantages of cassava (see Introduction), together with its being one of the principal crops grown by small farmers in marginal areas justify its development as an urban food. New technologies to improve the marketing and facilitate the processing of fresh cassava will help to stabilize and increase the level of urban consumption and the income generation potential of small-scale farmers, particularly in marginal areas. However, the successful competition of cassava in the future with other carbohydrate sources will also depend on certain other conditions, such as the reduction of market distortions that favour imports or other locally produced staple crops. Future efforts to overcome rapid post-harvest deterioration of cassava should take into account the needs and constraints of the farmers, traders and processors and also the preferences of the consumer

2.6 Potential of Controlling Post-Harvest Deterioration

Advances in biology and biotechnology have enabled scientists to dissect biochemical pathways, to isolate genes of interest from different organisms and to transfer these back into the original or alternative host plants. In agriculture this can lead to the production of plants with novel characteristics that would not be achievable through conventional breeding. The use of genetic manipulation techniques in breeding for resistance to physiological deterioration in cassava may alleviate the problems encountered by the use of conventional techniques. These problems are largely due to the highly heterozygous nature of the crop which makes generating the parental genotype highly improbable. To allow the potential of genetic manipulation to be realized, techniques are needed to integrate new genes into the cassava genome through genetic transformation of individual cells or tissues and to regenerate whole plants from the transformed material.

Table 2.2: Evaluation of Susceptibility to Physiological Deterioration of 26 Cultivars and Hybrids Harvested in Colombia (% Deterioration)

Cultivar	Site				
	CIAT-Palmira	Carimagua	Media-Luna	Caribia	P
CM 305-120	32.4	0.0	1.8	1.7	9.
CM 305-122	69.9	0.3	3.7	2.9	6
CM 321-188	60.6	0.0	0.4	4.3	6
CM 323-64	19.5	0.0	1.1	0.1	26
CM 340-30	29.4	0.0	0.9	0.9	14
CM 344-71	18.4	0.0	1.1	0.4	64
CMC 40	1.6	0.1	1.8	1.5	8.
MCol 113	12.0	0.0	3.9	0.3	32
MCol 1684	12.7	1.6	1.3	6.5	3.
MCol 72	50.2	4.0	1.4	1.1	2.
MPan 70	15.3	0.0	0.9	0.6	57
MPan 114	2.1	0.0	0.4	1.0	5.
MBra 12	23.3	0.0	0.4	0.1	10
Sata Dovio	12.6	0.0	2.7	0.2	72
Reg. negrita	31.6	0.0	0.9	0.1	34
MCol 22	90.1	0.0	1.4	1.7	3.

MCol 638	27.1	0.2	1.1	0.6	8
MPan 19	5.7	0.1	2.5	26.9	3
MEcu 82	8.4	1.1	1.8	1.8	4
MVen 77	3.0	0.3	1.6	6.9	2
Reg. amarilla	-	-	0.7	0.5	8
CMC 92	24.8	-	0.1	0.6	3
Secundina	58.6	-	1.9	24.0	-
Montero	70.1	17.5	10.5	15.7	-
Manteca	18.2	0.0	2.7	1.9	-
Llanera	0.6	0.6	0.8	-	2
Site mean:	27.9	1.1	1.8	4.1	2

Source: Wheatley (1982).

2.7 Physiological Deterioration in Cassava: Biochemistry of the Processes Involved

The rapid development of primary or physiological deterioration in cassava has been strongly associated with mechanical damage which occurs during harvesting and handling operations (Booth 1976). Frequently the tips are broken off as the roots are pulled from the ground and severance from the plant necessarily creates a further wound. In addition, transport from the field to the markets can result in further abrasion. In most cases physiological deterioration develops from sites of tissue damage and is initially observed as blue-black discoloration of the vascular tissue which is often referred to as vascular streaking. Initial symptoms are rapidly followed by a more general discoloration of the storage parenchyma.

In most plants, tissue damage results in a cascade of wound responses (Bowles, 1990) that quickly result in the defence of the wounded tissue and the subsequent sealing of exposed tissue by regeneration of a protective barrier (periderm formation). Common wound responses directly involved in defence include lytic enzymes (glucanase and chitinase), protease inhibitor proteins and hydroxyproline-rich glycoproteins production. Enzymes associated with the phenylpropanoid pathway, such as phenylalanine ammonia-lyase and chalcone synthase, lead to the biosynthesis of phenolics which may act directly as defence compounds (quinones, phytoalexins) or can form polymers, such as lignin, that render cell walls more resistant to water loss and attack from microbial enzymes.

Cassava roots when stored at high relative humidities (RH) of around 80 to 90 percent show a typical wound-healing response with periderm formation occurring in seven to nine days at 35 °C and 10 to 14 days at 25°C (Rickard, 1985). This response is notably slower than in the other tropical root crops, such as yam, which form a periderm in four to five days at 35°C (Passam, Read and Rickard, 1976). Booth (1976), however, demonstrated that periderm formation in cassava roots occurred around small v-shaped cuts within four to seven days at 35°C, indicating that the magnitude of the wound sustained can affect the time required for periderm formation. In cassava the formation of a wound periderm (curing) has been found to suppress the development of physiological deterioration (Booth, 1976).

Cytochemical investigations of changes occurring at the wound surface of cut cassava held at high storage RH have shown the development of a number of common plant wound responses (Rickard, 1982; 1985). Along with the development of colourless and coloured deposits at the wound surface and in the underlying cell layers (Figure 7) associated increases were observed in responses to cytochemical tests for phenols, lipids. Carbohydrates and lignin as well as in the activity of polyphenol oxidase and peroxidase. Additional changes were also observed using ultraviolet light with the development of whitish-blue fluorescence in the storage parenchyma. The cytochemical and general stains used were not, however, sufficiently specific to determine the exact identity of the material formed at the wound surfaces. However, the phenol test responses indicated the presence of flavanols (catechins and proanthocyanidins). The existence of lignin in the deposits which formed a barrier across the wound surface was not substantiated by either fluorescence or polarized light microscopy, indicating a polyphenolic rather than a lignified wound barrier. However, lignification of the cell walls in this area was substantiated by use of these microscopic techniques.

In cassava roots held at low storage humidity (less than 80 percent RH) the responses to injury do not remain localized at wound surfaces and physiological deterioration generally develops throughout the storage tissue within three to four days after harvest. Respiration experiments by Marriott, Been and Perkins (1979) have indicated that the initial development of physiological deterioration is associated with stress induced by water loss from wounds. Injured cassava roots were found to have a higher respiration rate when held under low humidity storage conditions. Microscopic observations have shown that the initial response to injury at low storage humidity involves the development of colourless deposits in the xylem parenchyma and an increase in storage parenchyma fluorescence. Material formed in the xylem parenchyma was observed to enter subsequently and occlude the xylem vessels along with the production of tyloses. The visual symptoms of vascular streaking were found to develop from discoloration of xylem parenchyma and vessel occlusions.

The initial symptoms of vascular streaking are rapidly followed by a more general discoloration of the storage parenchyma. Prior to the appearance of general tissue discoloration, colourless deposits and intense fluorescence were observed to develop in the storage tissue. Increases in the activities of polyphenol oxidase and peroxidase and a decrease in response to free phenols were noted to accompany the appearance of coloured deposits. The material formed in the xylem system and storage parenchyma gave similar cytochemical test responses to those obtained at the wound surface of cured roots. The presence of phenolic compounds during the development of physiological deterioration was also visually followed by the addition of cytochemical reagents to cut root pieces. Surface test responses for flavanols were strongly associated with areas of storage parenchyma discoloration.

The development of physiological deterioration throughout the storage tissues of cassava root after harvesting suggests the transmission of intercellular signals from the sites of damage. However, this topic has not been studied in cassava except for the production of ethylene. Like most other plant tissues (Hyodo, 1991), cassava has been found to produce ethylene in response to wounding. Ethylene production from damaged cassava roots was reported to occur after a lag period of about six hours and continued to increase over a 22hour period (Plumbley, Hughes and Marriott, 1981). Similar results were obtained by Hirose, Data and Quevedo (1984) after a lag phase of 16 hours with varietal differences affecting the rate of ethylene production (Figure 15). Experimental evidence to date suggests that ethylene is not directly involved in the development of physiological deterioration. Preharvest pruning, which is effective in suppressing physiological deterioration, had no significant influence on ethylene production following injury and the application of endogenous ethylene was not found to affect wound responses (Hirose, Data and Quevedo, 1984).

Physiological deterioration in cassava roots appears to share many of the common characteristics of plant wound responses. However, the sealing and healing aspects necessary for survival seem poorly expressed and are less localized in harvested cassava roots (Booth, 1976; Rickard and Coursey, 1981). This may be associated with the fact that cassava roots have no function in propagation, unlike other root crop storage organs (see Introduction). Normal responses to tissue injury result in wound repair, which reduces and finally eliminates the signals from damaged cells that elicit the cascade of wound reactions. In harvested cassava roots held under low humidity storage conditions (less than 80 percent RH) the cascade of wound responses is sustained and extends through the whole root, leading to physiological deterioration. It would thus appear that wound signal formation is maintained and the wound response processes are not reduced under these conditions.

Early studies reported a limited variation in the susceptibility of cassava cultivars to physiological deterioration. More recent studies have demonstrated that environmental growth conditions have a significant effect on the crop's development. Differences in root wound-healing properties have not been investigated in cassava or its wild relatives. It is possible that an adequate root healing response has been lost from cassava as this characteristic was not a selection priority.

2.9 Microbial Deterioration of Cassava: Organisms Involved

It is known that cassava roots will not store well, have a short storage life, will not keep for more than a few days and are highly perishable (Rickard and Coursey, 1981) without giving any indication of the nature or even the symptoms of the deterioration processes involved. Other publications refer loosely to "rots" or "decay", giving the impression that the deterioration is essentially due to microbiological infection. The number of different species of fungi and bacteria isolated from roots stored under different conditions shows that post-harvest decay of cassava is a complex matter, involving more than a single initial organism. Two distinct specific types of rot have been described by Majumder (1955), a dry rot occurring under aerobic conditions and caused by an unidentified *Rhizopus sp.* and a soft rot which developed under anaerobic conditions caused by a *Bacillus sp.* Under West African conditions, Affran (1968) and Doku (1969) have suggested an association between post-harvest decay and preharvest infection of the roots with white thread disease, *Rigidoporus lignosis* (Klotzsch) Imasaki.

A more detailed investigation (Ekundayo and Daniel, 1973) indicated that soft rot of cassava roots was caused by a complex of fungi; *Lasiodiplodia theobromae* (Pat.) Griff. et Maubl., *Aspergillus nigervan* Tieghem, *Aspergillus flavus* Link, *Cylindrocarpon candidum* (Link) Wollenw and *Trichoderma harizianum* Rifia, the first organism being the most important. Although these workers clearly associated the decay with invasion through wounds, they concentrated on the later stages of decay rather than on the initiation of postharvest deterioration. Wegmann (1970), who also worked mainly with material that was in an advanced stage of deterioration, isolated A. niger together with *"Cylindrium cladostrinum "* (presumably *C. clandestrinium* (Corda) Saccardo) and unidentified *Penicillium* and *Cladosporium spp.* Studies by Burton (1970) on cassava shipped from Puerto Rico to the United States indicated that, while *Diplodia manihotis* (Sacc.) was the most serious market disease, a number of other fungal pathogens were also isolated, including species of *Fusarium, Mucor, Phomopsis, Rhizopus* and *Trichoderma spp.* Booth (1976), in a more detailed study on the deterioration of cassava, isolated from the surfaces of cassava roots various species of *Pythium, Mucor, Rhizopus, Penicillium, Aspergillus, Fusarium, Cladosporium, Glomerella, Gloeosporium, Rhizoctonia, Bacillus,* *Xanthomonas*, *Erwinia*, *Agrobacterium* and many saprophytic bacteria. However, Booth was consistently unable to isolate any specific microorganism from the advancing margins of deterioration in the flesh of the rots. It was therefore concluded that the earlier stages of postharvest deterioration, manifest as discoloration of the vascular tissue, were not inherently the results of attack by pathogens and that the later stages were essentially the decay of already moribund tissue caused by a wide variety of saprophytes.

In a later study by Noon and Booth (1977) a number of microorganisms, both fungi and bacteria, were isolated from severely decayed cassava roots. The pathogenicity of the organisms was tested by inoculating freshly harvested, surface-sterilized roots. Vascular streaking developed in the roots throughout the 14-days storage period under tropical ambient conditions (25°C). Within four days of harvest, over 50 percent of the roots showed symptoms of vascular streaking. Some of the isolated microorganisms proved to be pathogenic when introduced into healthy cassava roots, notably *Botryodiplodia theobromae* Pat. and to a lesser extent *Aspergillus flavus* Link, *Trichoderma harizianum* Rifia and *Fusarium solani* (Mart.) (Table5). In some cases inoculated roots developed symptoms of vascular streaking (Figure 3), but there was no evidence that this was associated with the introduced organisms. In these cases the inoculated organisms could not be recovered from the advancing fronts of discoloration, although they could be recovered from the margins of the grossly necrotic areas. In other cases rotting was caused by the inoculated pathogen, but no vascular streaking occurred. The findings of Noon and Booth, which concluded that vascular streaking is a physiological process, were substantiated by a detailed cytochemical study of the development of vascular streaking using light and electron microscopic techniques. Rickard, Marriott and Gahan (1979) were unable to detect any signs of microbial infection during the early stages of vascular discoloration and, following results obtained using *Phycomycetes*, *Taniguchi* and Data (1984) also concluded that there was no direct relationship between vascular streaking in cassava roots and microbial decay.

TABLE 2.3: Microorganisms isolated from damaged cassava roots

Organism	Disease
Bacillus sp.	Minor wet rot
	Post-harvest secondary deterioration
Corynebacterium manihot	Root fermentation
Armillanella (armillana) mellea	Young root necrosis
	Minor dry rot
Aspergillus spp.	Post-harvest secondary deterioration
Circinella sp.	Post-harvest decay
Clitocybe tabescens	Root rot
Cylindrocarpon candidum	Post-harvest deterioration
Diplodia manihotis	Root rot
Erwinia sp.	Minor wet rot
	Young root necrosis
Fusarium spp.	Minor wet rot
Ganoderma pseudoferrum	Red root rot
Geotricum candida	Root fermentation
Helicobasidium compactum	Minor dry rot

Lasiodiplodia theobromae	Post-harvest secondary deterioration
Mucor sp.	Post-harvest decay
Penicillium spp.	Post-harvest decay
Phaeolus manihotis	Root rot
Phytophthora spp.	Young root necrosis
	Wet rot
Pythium sp.	Young root necrosis
	Minor wet rot
Rhizoctonia sp.	Root rot
Rhizopus spp.	Post-harvest secondary deterioration
Rigidoporous (Fomes lignosis)	White root
Rosellinia spp.	Black rot
Scleroinia sp.	Young root necrosis
Sclerotium rolfsli	Young root necrosis
	Minor dry rot
Sphaceloma manihoticola	Minor root rot
Sphacrostilbe repens	Root rot
Syncephalastrum sp.	Post-harvest decay
Trichoderma sp.	Post-harvest deterioration
Xanthomonas manihotis	Cassava bacteria blight and minor dry rot
Unknown	Frog skin disease

Source: Booth (1976)

On the basis of his observations, Booth (1976) made a clear distinction between primary deterioration of stored cassava roots, considered to be an endogenous physiological process and secondary deterioration. Microbial activity is the most common cause of secondary deterioration although fermentation or root tissue softening can also occur. Primary deterioration is the initial and major cause of the loss of acceptability, while secondary deterioration can become more important later. On occasion secondary deterioration may be the initial cause of loss and in these instances symptoms of vascular streaking frequently occur ahead of the rots. Pre- and post-harvest root rot diseases of cassava have been reviewed by Booth (1978) and are summarized as follows:

Fig 2.4: Mean distance[1] of tissue decay from points of inoculation of healthy roots with microorganisms isolated from deteriorated cassava roots

Microorganism	**Mean distance of tissue decay (mm)[3]**
Aspergillus flavus LK ex Fr	5
Bacterial isolate 1	1
Bacterial isolate 2	2
Botryodiplodia theobromae Pat	26
Fusarium solani (Mart) Sacc	7
Mucor sp	2
Penicillium sp, isolate 1	1
Penicillium sp, isolate 2	1
Rhizopus sp	1
Trichoderma harizianum Rifai	10

Source: Booth1976.

Notes:

1 Distance measured 14 days after inoculation.

2 Microorganism isolated 14 days after harvest of roots

3 Mean for two experiments. each consisting of four replicates

Secondary deterioration occurs when pathogens penetrate through wounds and bruises inflicted during harvesting and handling. Storage at high humidity encourages fungal rotting but is also necessary for effective wound healing. The use of a microbial protectant is therefore often required with preservation methods that are favourable to root curing, such as storage in plastic bags

CHAPTER THREE

3.0 Materials and Methods

This chapter reveals the various methods, techniques and steps taken to evaluate the postharvest losses of cassava and method of storage available in kogi state. This report is a survey work, which involves data collection through questionnaire administration and oral interview. Kogi state known for its cassava production in the middle belt region of Nigeria was selected for the survey work.

Ten local government areas out of twenty one in the state were selected. The selected local government areas are Okehi, Adavi, Ogorimagongo, Kogi, Kabba-bunu, Lokoja, Olamaboro, Igala-Mela/Odolu, Ankpa, and Idah local government area of kogi state.

3.1 Materials

The cassava plantations used for this study was selected from ten local government area (Okehi, Adavi, Ogorimagongo, Kogi, Kabba-bunu, Lokoja, Olamaboro, Igala-Mela/Odolu, Ankpa, and Idah) in Kogi state, Nigeria. Ten farm locations were chosen and the estimation was based on last season harvest.

Cassava is widely cultivated staple crop in the tropics (Oyenuga, 1968) wherein Nigeria is located. According to FAO world food presective repot submitted to PANA;it was stated that Nigeria is leading the Africa countries produced 26.0 million tuber tones out of the continents 72.7 million tuber tones and world's figure of 158.1 million tuber tones of cassava.

3.2 Method of Data Collection

A number of questions were drafted based on the information needed from the direct source that is, the actual information direct from the farmers. The questionnaires were carefully administered to the farmers and verbal interview were conducted for the farmers and also the traders throughout the ten local government areas selected. This method eliminates discrimination and favourism of some village or sets of people.

Using this method, ten cassava farmers were selected from each local government area which gave a total of one hundred cassava farm land visited throughout the ten local government areas selected. The method employed was that the ten largest cassava farms in the local government area were picked, and cassava traders were interviewed at the market, although not all the villages or the local government areas has cassava market. Care was taken to ensure good distribution of sample over space. The table below shows the distributions of various local government area and total numbers of farms and traders visited.

Table 3.1: Table of the Farmers and Traders Visited

Local govt areas	no. Of farm visited	no. Of traders interviewed
Okehi	10	4
Adavi	10	2
Ogori-magongo	10	-
Lokoja	10	3
Kogi	10	-
Kabba-bunu	10	5
Olamaboro	10	2
Idah	10	6
Igala-Mela/Odolu	10	2
Ankpa	10	3
	100	27

3.2.1 Storage Method

The storage method common among the visited local government areas are the underground method i.e. leaving the cassava roots unharvested till it is needed and the other method is the covering of the roots with fresh leaf. This method of covering the roots with fresh leave is common with the just harvested cassava roots waiting for transporting and at the market, this is done to prevent drying from direct sun rise. It can only preserve the roots for some few days (4 – 6 days).

3.2.2 Causes of Losses

The major causes of losses in cassava are the fast deterioration of the roots, which make the storage almost impossible. cassava losses in most area visited caused by:

3.2.2.1 Field Losses

When cassava is been pulled from the ground, some pieces are left under the soil, this were determined by selecting some ridges and re-digging it, the total cassava roots recovered was taken and the average of the roots was used to multiply the rest of the area where cassava were removed. The broken roots and small pieces that were left on farm too were taken care of.

3.2.2.2 Transportation Losses

The harvested cassava roots are collected together and then moved to a place within the farm or at the outsketch of the farm; where it can easily be loaded into the vehicle (motorable). During this process, some roots are left unpacked from the farm and also some point where the roots are been gathered which is far from the farm to motorable point is conveyed by headpan, (human being), bicycle or motorcycle. When these transportation is going on, some fall on the way without knowing and due to bad road, the load can fall from the human head and even the motorcycle and the bicycle. When this happened, some get broken which devalue the produce in the market and these broken roots are most of the time thrown away.

3.2.2.3 Storage Losses

Storage losses is the largest as far as cassava is concerned, the farmers don't recognize any other losses except storage losses, so therefore the information given by the farmers was used as the storage losses only. The table below show the losses given by the farmers themselves in each local government areas visited; these were given in loads of pick ups, head pans, tonnes and in percentage.

Table 3.2: Okehi Local Government Area

Farm visited	Land mass (acres)	Productions (pickups)	Losses
1	1-5	25	2 pickups
2	5-10	142	2.5 pickups
3	1-5	85	4 pickups
4	>10	240	15%
5	1-5	12	5%
6	1-5	17	6 baskets
7	>10	250	5 pickups
8	5-10	86	about 7%
9	1-5	12	not given
10	1-5	10	11 headpan

Table 3.3: Adavi Local Government Area

Farm visited	Land mass (acres)	Productions (pickups)	Losses
1	5-10	133	8%
2	1-5	21	3 pickups
3	>10	311	10 pickups
4	1-5	16	12%
5	5-10	118	12 pickups
6	> 10	263	21%
7	1-5	13	10%
8	1-5	15	6 headpan
9	5-10	42	1.5 pickups
10	> 10	300	25%

Table 4.3: Ogori-Magongo Local Government Area

Farm	Land mass (acres)	Yield (kg)	Field losses(kg)	Transportation Losses(kg)	Storage Losses(kg)	Dried storage losses(kg)	Total losses(kg)
1	1-5	19305	30	50	742.5	-	822.5
2	1-5	17820	-	-	-	30	30
3	5-10	193050	90	120	19305	-	19515
4	5-10	172260	-	-	22393.8	25	22418.8
5	5-10	237600	35	20	4455	-	4510
6	1-5	11137.5	56	-	99	28	183
7	1-5	31185	-	-	198	-	198
8	1-5	22275	27	-	1485	-	1512
9	1-5	31482	17	-	2227.5	-	2244.5
10	<1	7425	-	-	99	21	120
		743539.5	255	190	51004.8	104	51553.8

Table 4.4: Kogi Local Government Area

Farm	Land mass (acres)	Yield (kg)	Field losses(kg)	Transportation Losses(kg)	Storage Losses(kg)	Dried storage losses(kg)	Total losses(kg)
1	1-5	31185	29	70	396	-	495
2	1-5	8910	84	66	148.5	-	298.5
3	5-10	181170	-	125	7425	-	7550
4	5-10	151470	122	190	14850	-	15162
5	5-10	169290	123	33	5197..5	-	5353.5
6	1-5	19305	-	-	99	30	129
7	<1	7425	-	-	-	25.5	25.5
8	5-10	169290	99	100	3712.5	-	3911.5
9	1-5	47520	71	-	396	-	467
10	>10	343035	201	1000	23760	-	24961
		1128600	729	1584	55984.5	55.5	58344

Table 3.5: Lokoja Local Government Area

Farm	Land mass (acres)	Yield (kg)	Field losses(kg)	Transportation Losses(kg)	Storage Losses(kg)	Dried storage losses(kg)	Total losses(kg)
1	5-10	178200	45	190	17820	-	18055
2	>10	326700	97	226	14850	-	15173
3	1-5	22275	36	-	132	-	168
4	5-10	74250	82	54	37125	-	37261
5	1-5	34155	66	99	8538.75	-	8703.75
6	1-5	31185	33	-	2970	-	3003
7	5-10	50490	165	-	12622.5	-	12787.5
8	1-5	44550	36	-	14850	15	14901
9	5-10	148500	180	80	8167.5	-	8427.5
10	5-10	179685	110	50	26952.75	10	27122.75
		1089990	850	699	989364.75	25	145602.5

Table 4.6: Kabba-Bunu Local Government Area

Farm	Land mass (acres)	Yield (kg)	Field losses(kg)	Transportation Losses(kg)	Storage Losses(kg)	Dried storage losses(kg)	Total losses(kg)
1	5-10	148500	155	160	29700	-	30015
2	5-10	231660	120	110	22275	-	22505
3	5-10	115830	63	90	5197.5	-	5350.5
4	>10	280665	210	200	29700	33	30143
5	5-10	197505	99	-	89100	5	89214
6	>10	445500	199	1445	31185	-	32829
7	5-10	129195	83	90	5940	5	6118
8	5-10	178200	165	-	30294	-	30459
9	1-5	8910	33	-	178.2	-	2112
10	5-10	163350	230	99	14850	15	15194
		1899315	1360	2194	258419.7	58	263939.5

Table 4.7: Olamaboro Local Government Area

Farm	Land mass (acres)	Yield (kg)	Field losses(kg)	Transportation Losses(kg)	Storage Losses(kg)	Dried storage losses(kg)	Total losses(kg)
1	5-10	96525	66	-	6682.5	-	6748.5
2	>10	297000	302	380	74250	-	74932
3	<1	2970	68	-	132	10	210
4	5-10	75735	120	-	5940	-	6060
5	5-10	29700	132	190	2970	-	3292
6	>10	415800	1175	490	103950	-	105615
7	5-10	56430	63	-	14107.5	-	14170.5
8	5-10	89100	495	55	8910	-	9460
9	5-10	121770	122	125	5197.5	-	5444.5
10	1-5	23760	99	-	460	15	574
		1098790	2642	1240	222599.5	25	226506.5

Table 4.8: Idah Local Government Area

Farm	Land mass (acres)	Yield (kg)	Field losses(kg)	Transportation Losses(kg)	Storage Losses(kg)	Dried storage losses(kg)	Total losses(kg)
1	1-5	14850	77	-	132	-	209
2	<1	4455	-	-	99	15	114
3	1-5	14850	38	-	2970	5	3013
4	5-10	164835	199	450	17077.5	-	17726.5
5	>10	460350	460	1005	23760	-	25225
6	>10	415800	330	900	20790	-	22020
7	1-5	22275	121	-	2970	-	3091
8	5-10	23760	127	-	2970	-	3097
9	5-10	169290	363	150	8910	-	9423
10	5-10	181170	313	200	6682.5	-	1795.5
		1471635	2028	2300	92169	20	91114

Table 4.9: Igala Mela/Odolu Local Government Area

Farm	Land mass (acres)	Yield (kg)	Field losses(kg)	Transportation Losses(kg)	Storage Losses(kg)	Dried storage losses(kg)	Total losses(kg)
1	5-10	66825	241	-	8910	25	9176
2	5-10	94297.5	184	-	29700	17	29901
3	>10	466290	733	1090	65280.6	-	67103.6
4	>10	371250	1023	980	5940	-	7943
5	1-5	22275	110	-	528	-	638
6	>10	415800	1110	520	14850	-	16480
7	5-10	172260	512	66	68904	-	69482
8	5-10	163350	432	-	4083.75	5	4520.75
9	5-10	178200	199	99	24948	-	25246
10	5-10	172260	210	125	5940	-	6275
		2122807.5	4754	2880	229084.35	47	236765.35

Table 4.10: Ankpa Local Government Area

Farm	Land mass (acres)	Yield (kg)	Field losses(kg)	Transportation Losses(kg)	Storage Losses(kg)	Dried storage losses(kg)	Total losses(kg)
1	1-5	17820	92	-	2227.5	0.8	2320.3
2	>10	194502	811	180	27230.28	-	28221.28
3	5-10	222750	299	-	23760	-	24059
4	>10	442530	2277	850	14850	-	17977
5	5-10	187110	377	200	23760	-	24337
6	5-10	148500	489	99	4455	-	5043
7	>10	445500	754	-	14850	-	15604
8	1-5	68310	-	-	2970	11	2981
9	5-10	326700	525	66	11880	-	12471
10	5-10	222750	258	125	3712.5	-	4095.5
		1907472	5505	1520	129695.25	11.8	137109.08

4.2 Result Analysis

From the result in table 4.1, the values were used to analyze the cassava produce and losses in each local government areas and also the total cassava produce and its losses; these were represented in pie and bar chart. From the bar charts below, 1 is the field losses, 2 is the transportation losses, 3 is the storage losses and 4 is dried storage losses

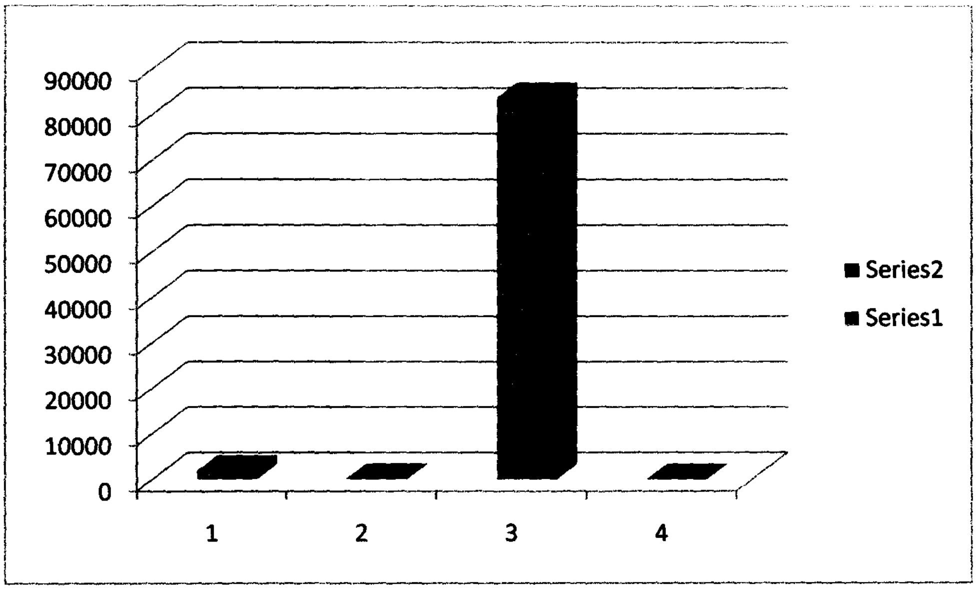

Fig 4.1Losses Bar chart in Okehi local government area;

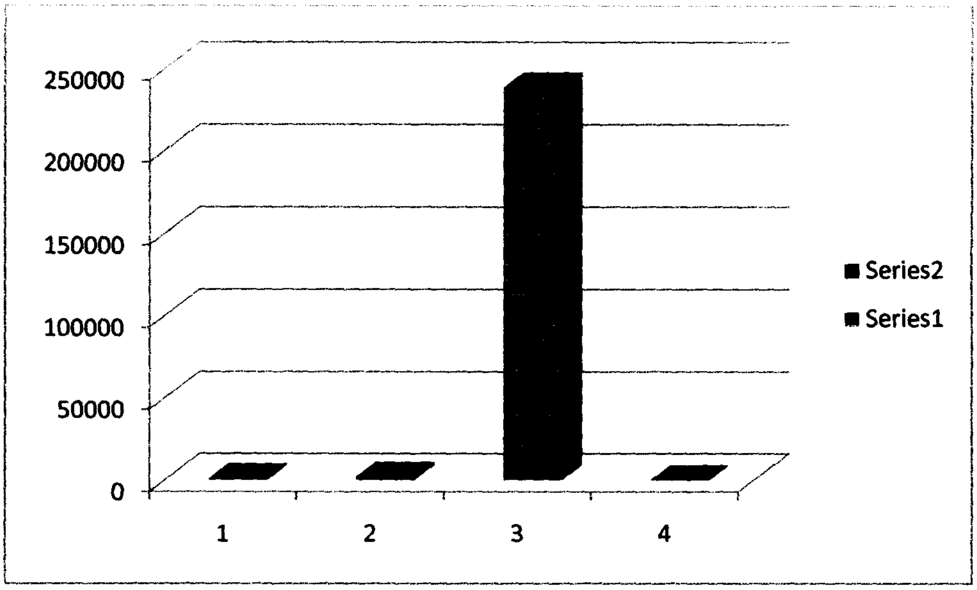

Fig 4.2 Losses Bar chart in Adavi local government area;

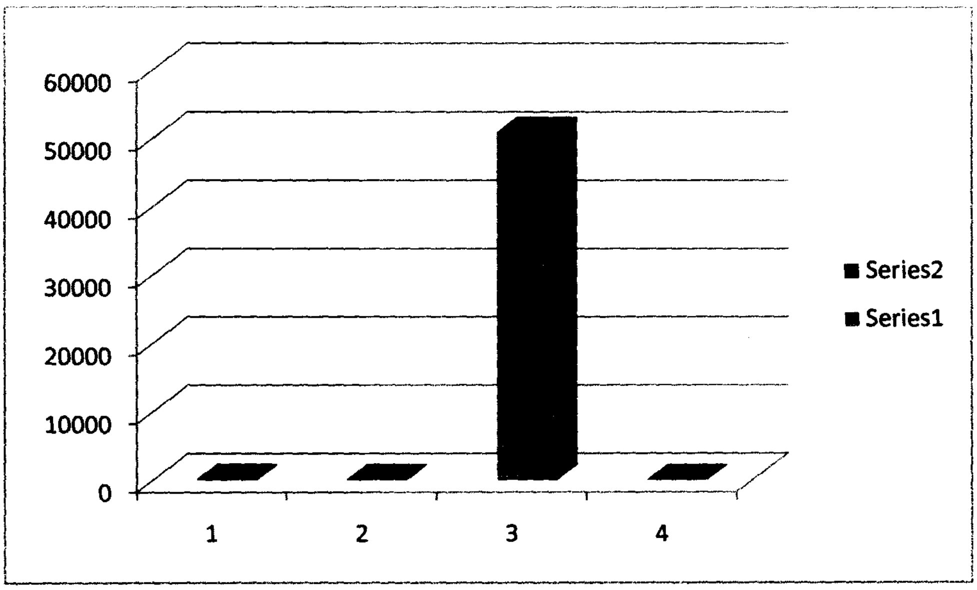

Fig 4.3 Losses Bar chart in Ogori-magongo local government area;

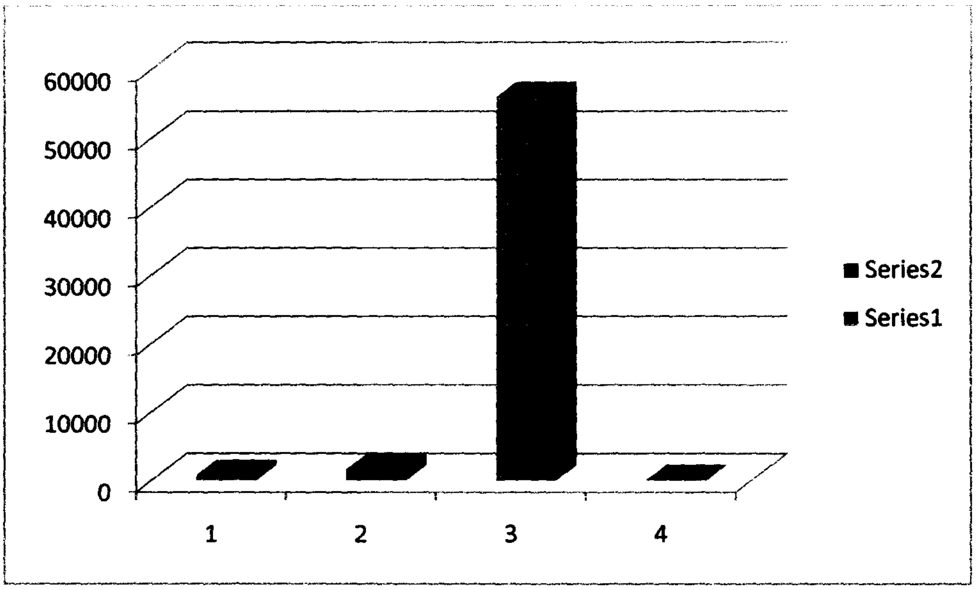

Fig 4.4 Losses Bar chart in Kogi local government area;

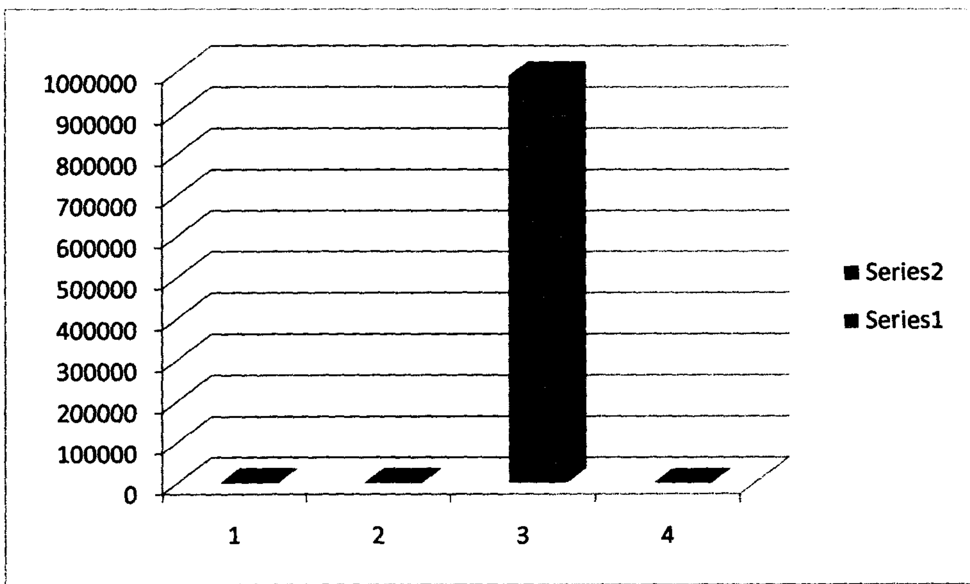

Fig 4.5 Losses Bar chart in lokoja local government area;

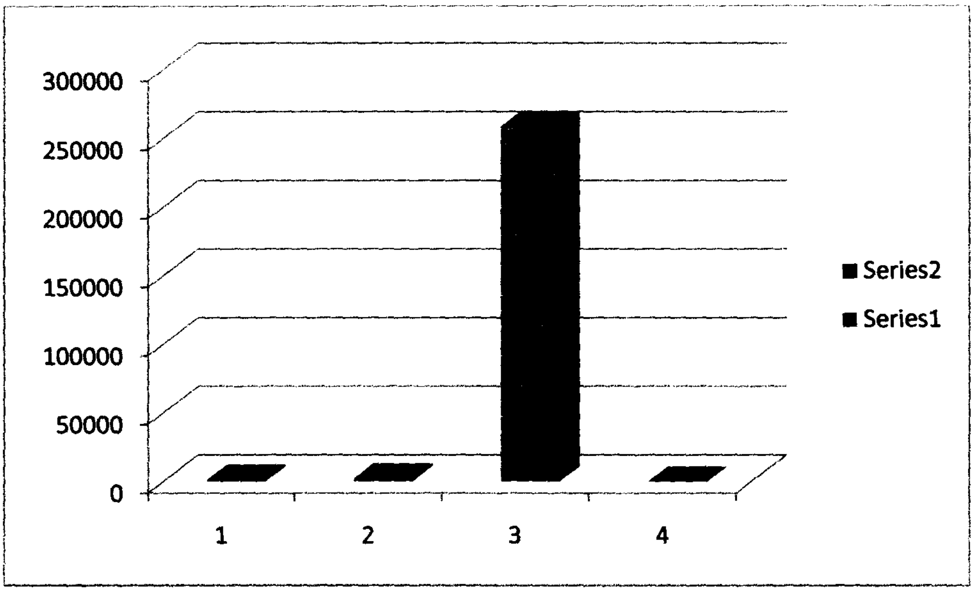

Fig 4.6 Losses Bar chart in kabba-Bunu local government area;

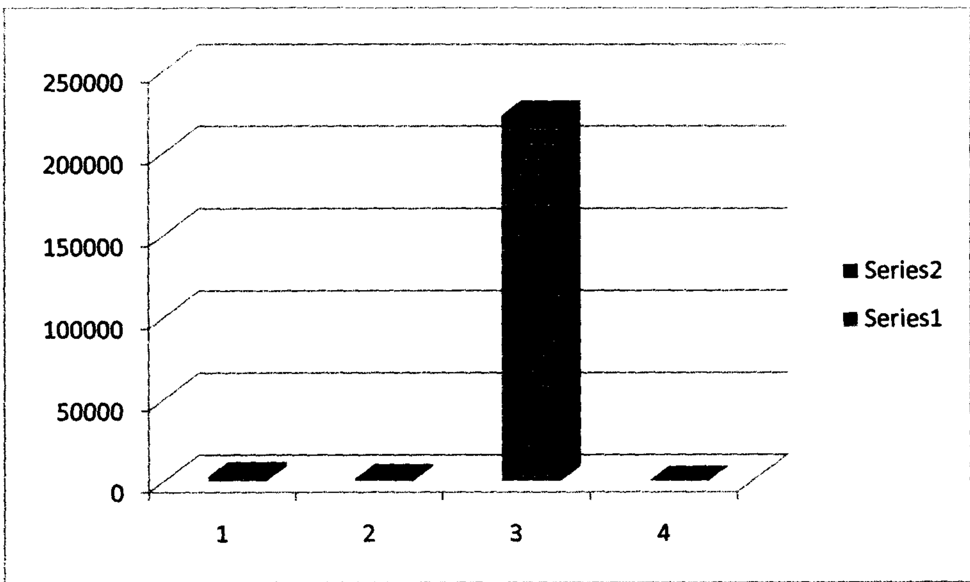

Fig 4.7 Losses Bar chart in Olamaboro local government area;

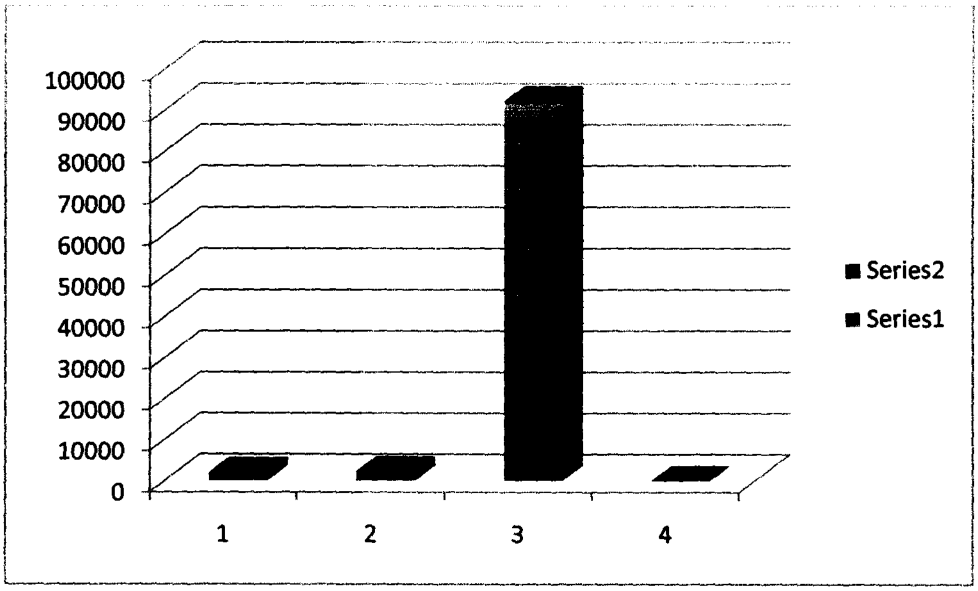

Fig 4.8 Losses Bar chart in Idah local government area;

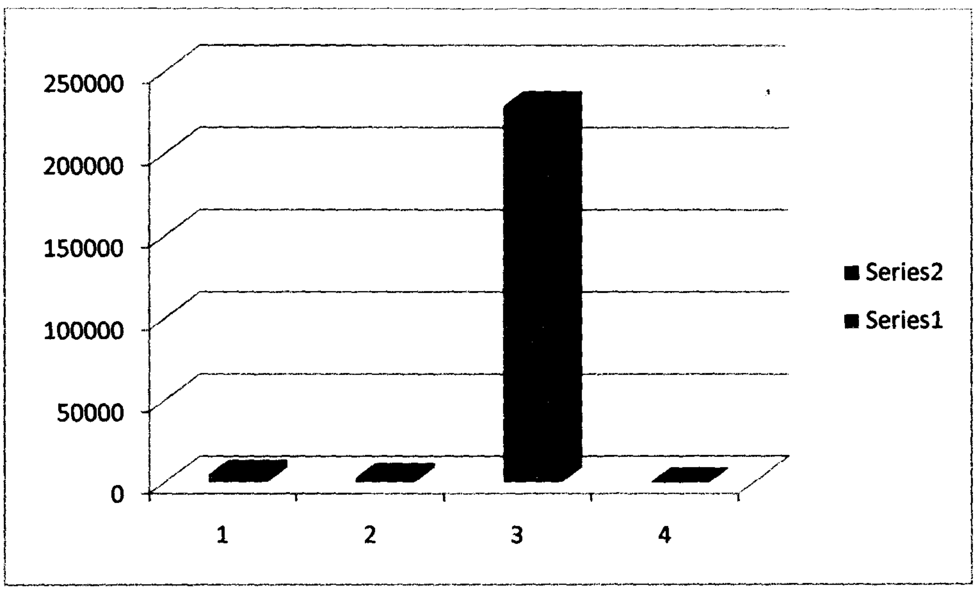

Fig 4.9 Losses Bar chart in Igala-Mela/Odolu local government area;

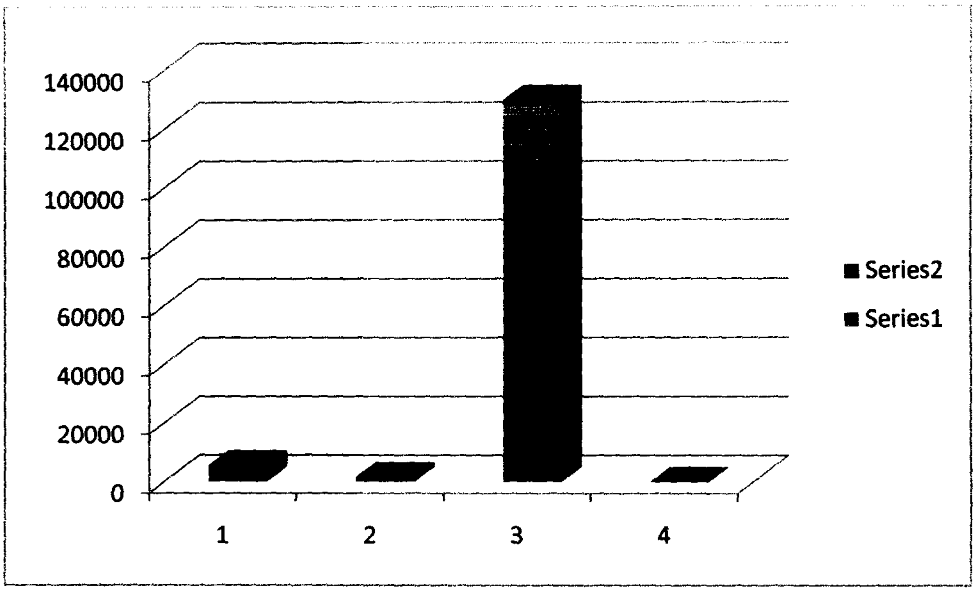

Fig 4.10 Losses Bar chart in Ankpa local government area;

The pie charts below show the percentage production and losses. In the charts, Fig 1 represents the produce and Fig 2 represents the losses

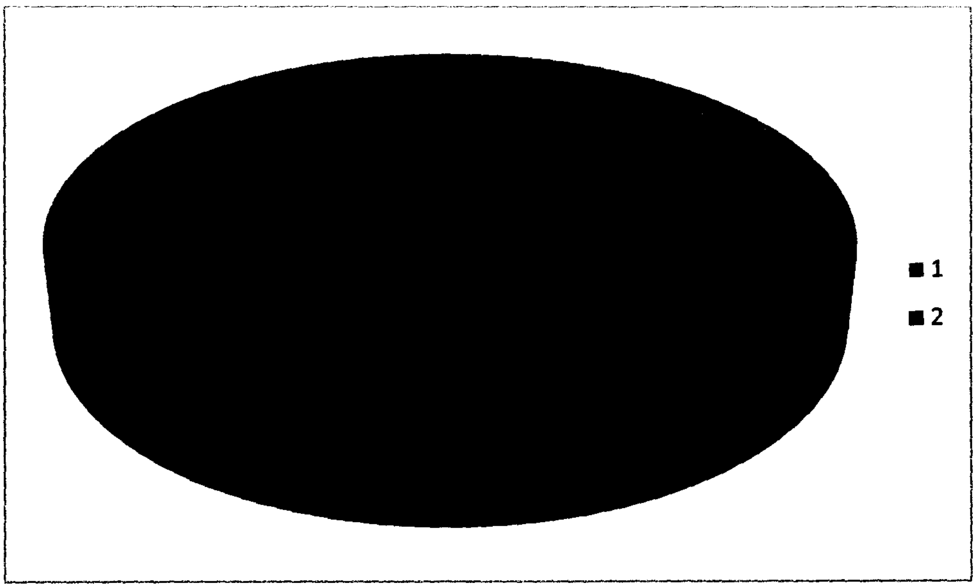

Fig 4.11 Pie Chart Showing Production and Losses in Okehi Local Government Area

In the above chart, 1 = 92% and 2 = 8%

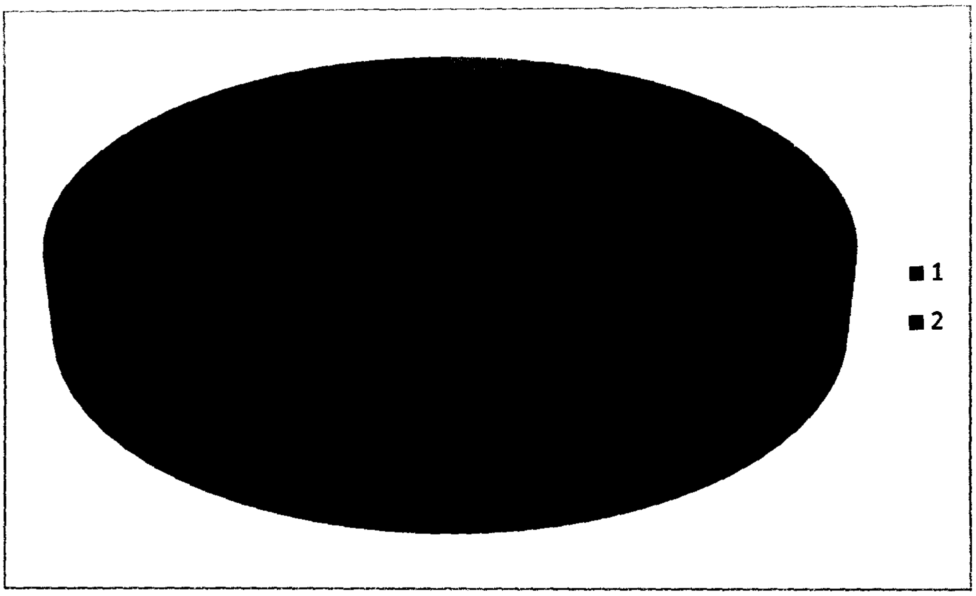

Fig 4.12 Pie Chart Showing Production and Losses in Adavi Local Government Area

In the above chart, 1 = 88% and 2 = 12%

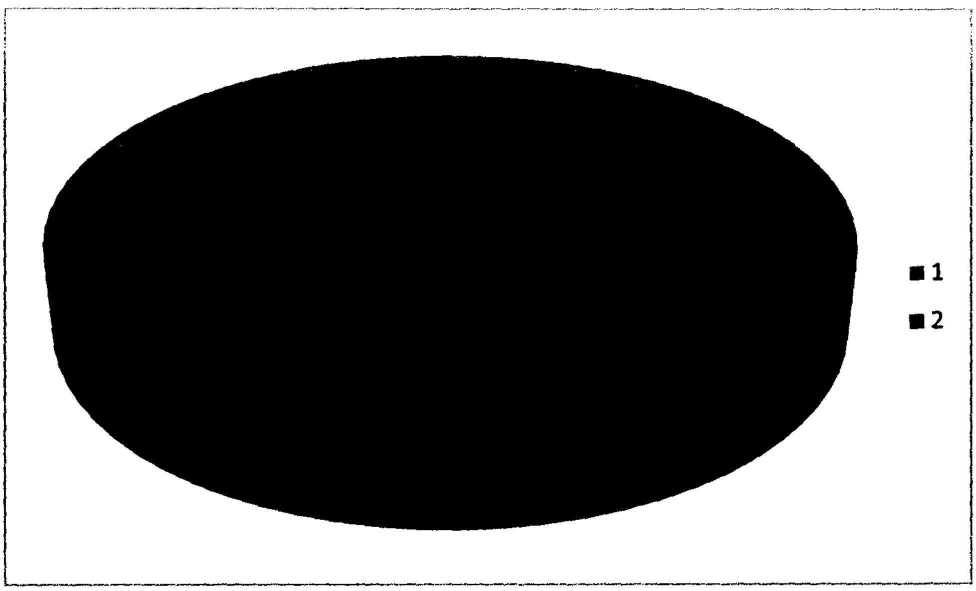

Fig 4.13 Pie Chart Showing Production and Losses in Ogori-magongo Local Government Area

In the above chart, 1 = 94% and 2 = 6%

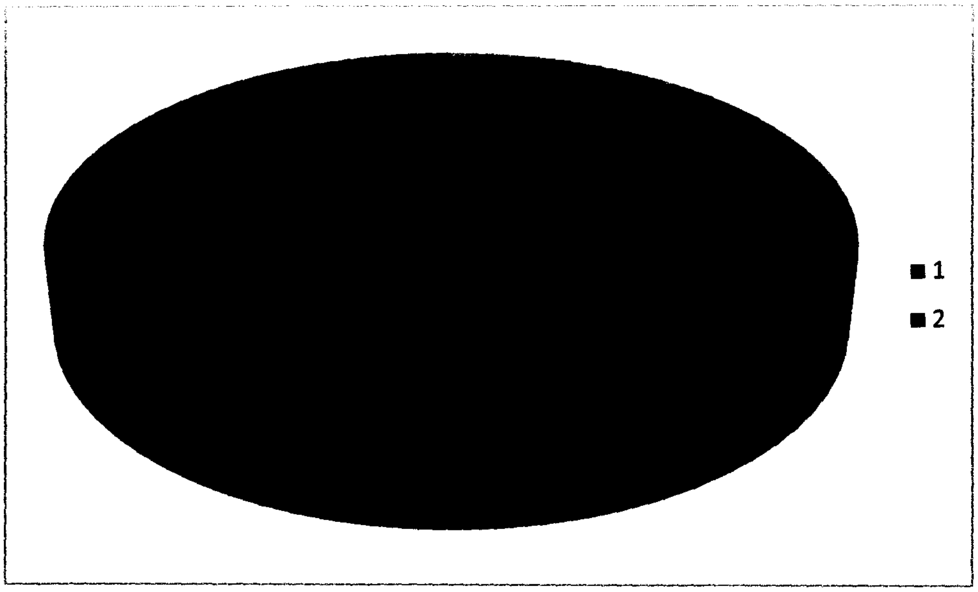

Fig 4.14 Pie Chart Showing Production and Losses in Kogi Local Government Area

In the above chart, 1 = 95% and 2 = 5%

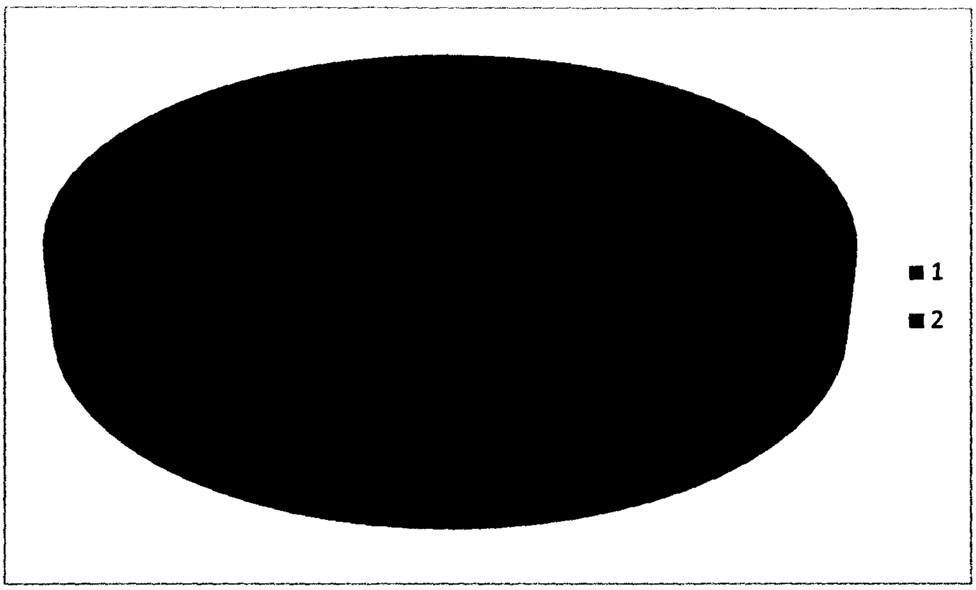

Fig 4.15 Pie Chart Showing Production and Losses in Lokoja Local Government Area

In the above chart, 1 = 88% and 2 = 12%

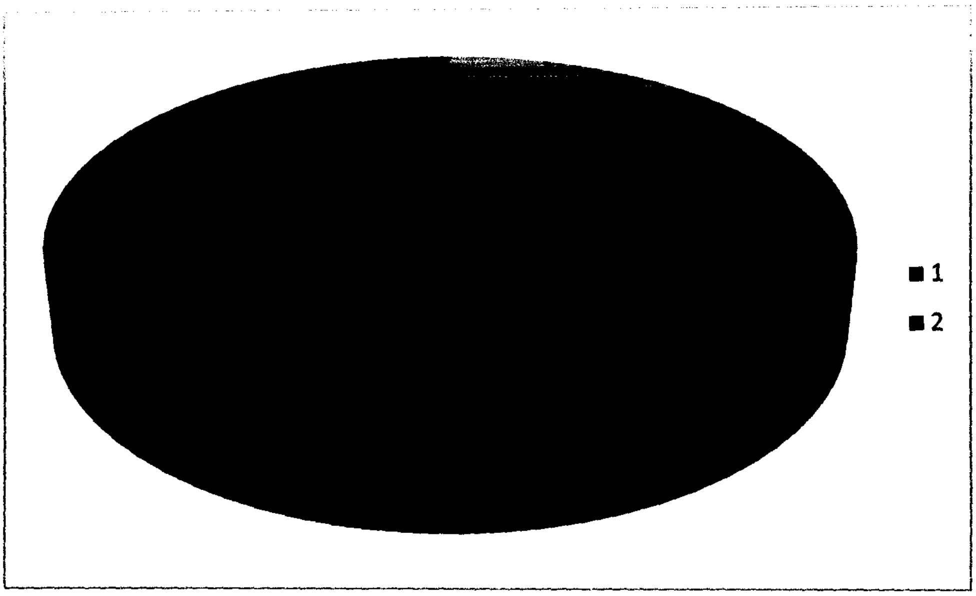

Fig 4.16 Pie Chart Showing Production and Losses in Kabba-Bunu Local Government Area

In the above chart, 1 = 88% and 2 = 12%

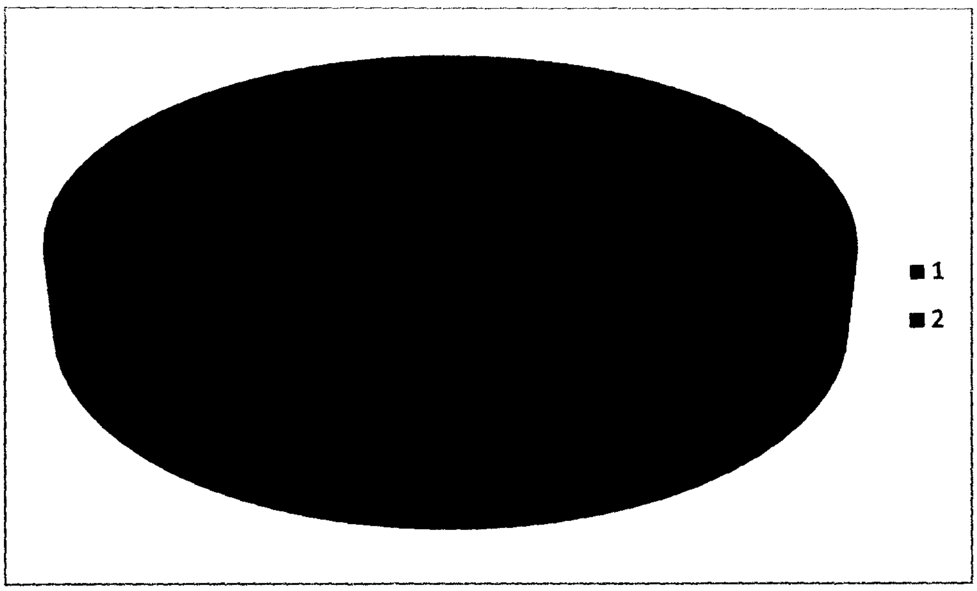

Fig 4.17 Pie Chart Showing Production and Losses in Olamaboro Local Government Area

In the above chart, 1 = 83% and 2 = 17%

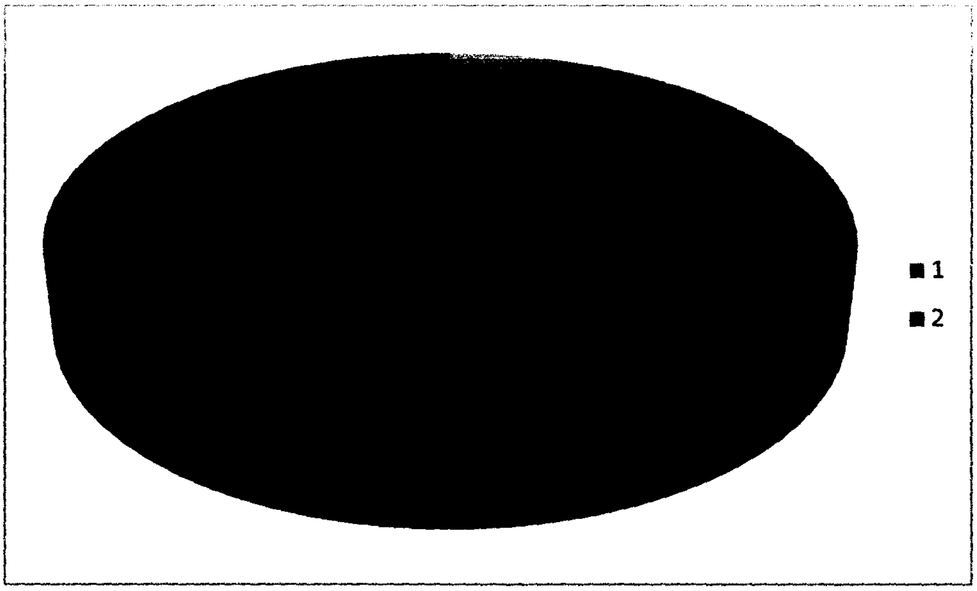

Fig 4.18Pie Chart Showing Production and Losses in Idah Local Government Area

In the above chart, 1 = 94% and 2 = 6%

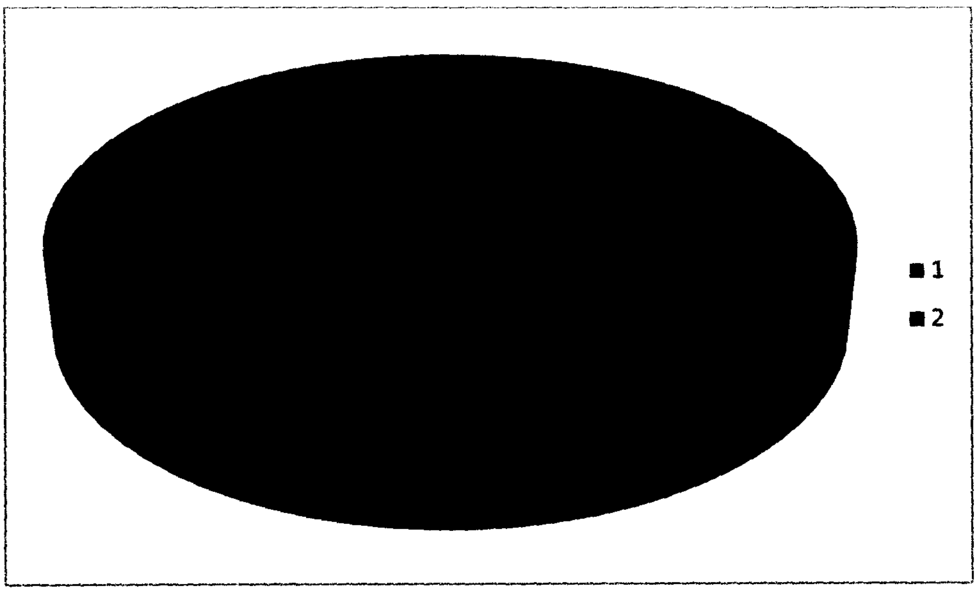

Fig 4.19 Pie Chart Showing Production and Losses in Igala-Mela/Odolu Local Government Area

In the above chart, 1 = 90% and 2 = 10%

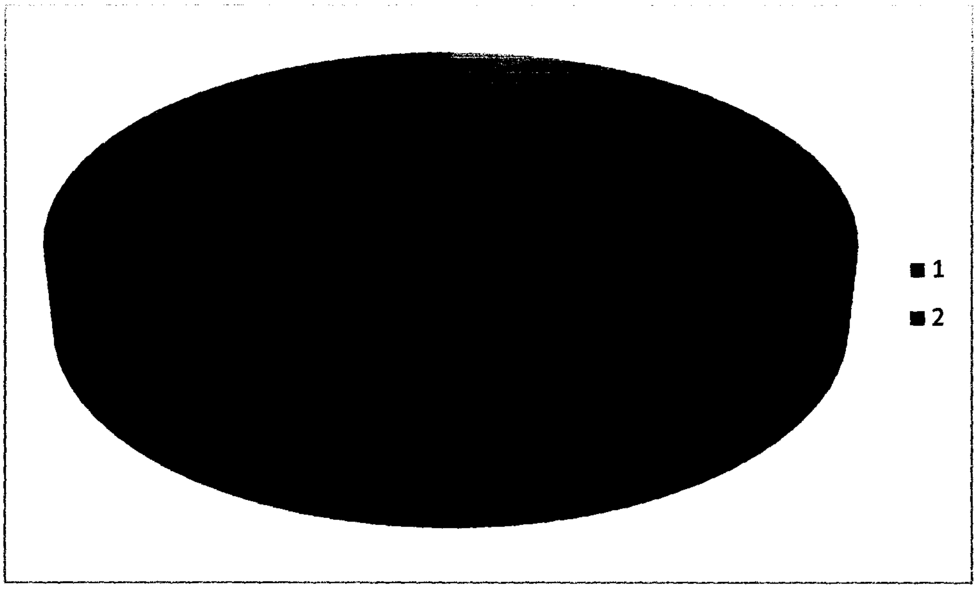

Fig 4.20 Pie Chart Showing Production and Losses in Ankpa Local Government Area

In the above chart, 1 = 93% and 2 = 7%

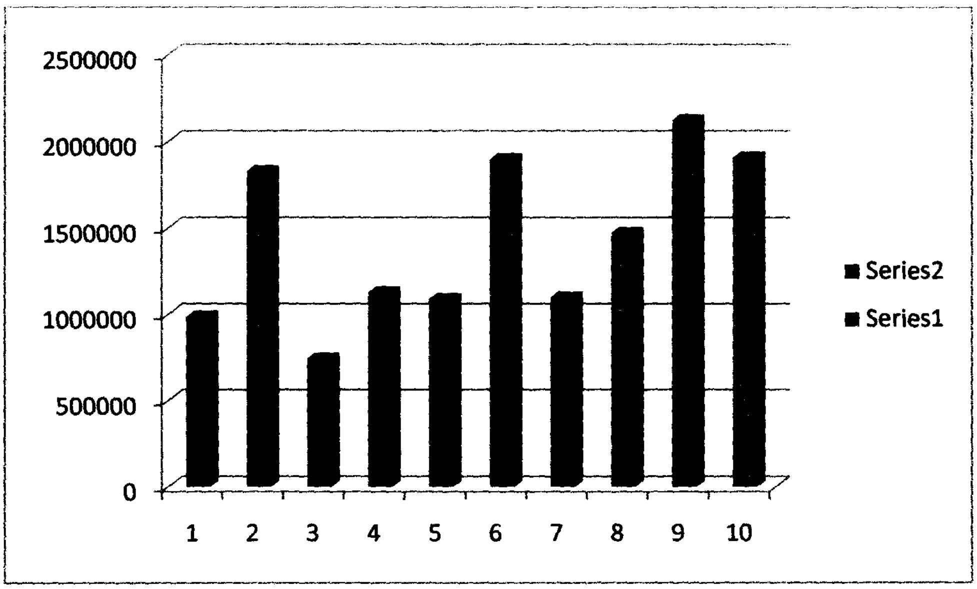

Fig 4.21 Bar Chart showing total cassava roots production in each of the ten local government areas selected.

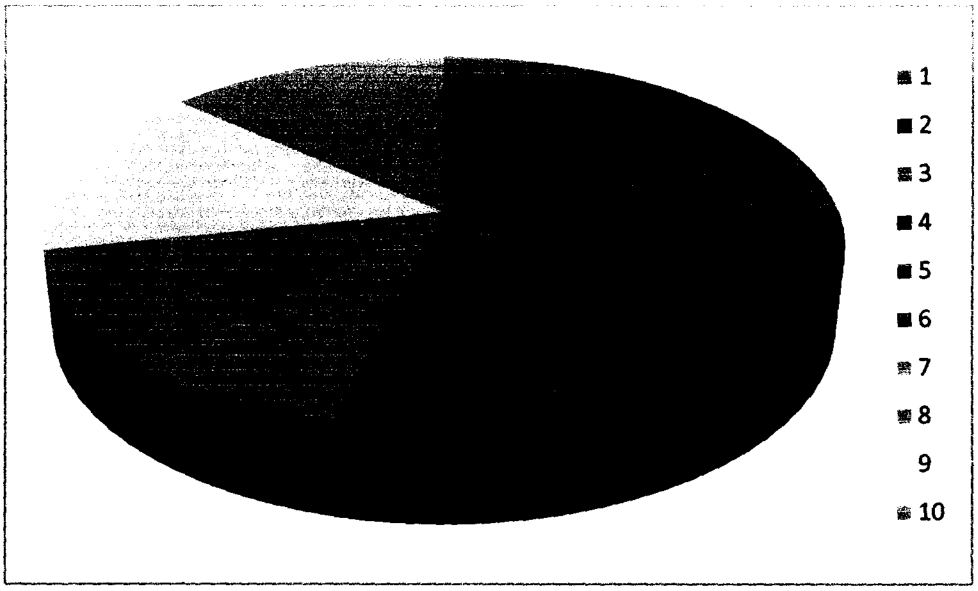

Fig 4.22 Pie Chart Showing Total Cassava Roots Production in Each of the Ten Local Government Areas Selected.

The percentage of the total cassava roots produced in all the ten local government area selected represented in the chart above are as follows; 1 = 7%, 2 = 13%, 3 = 5%, 4 = 8%, 5 = 8%, 6 = 13%, 7 = 8%, (8) = 10%, (9) = 15% and (10) = 13%.

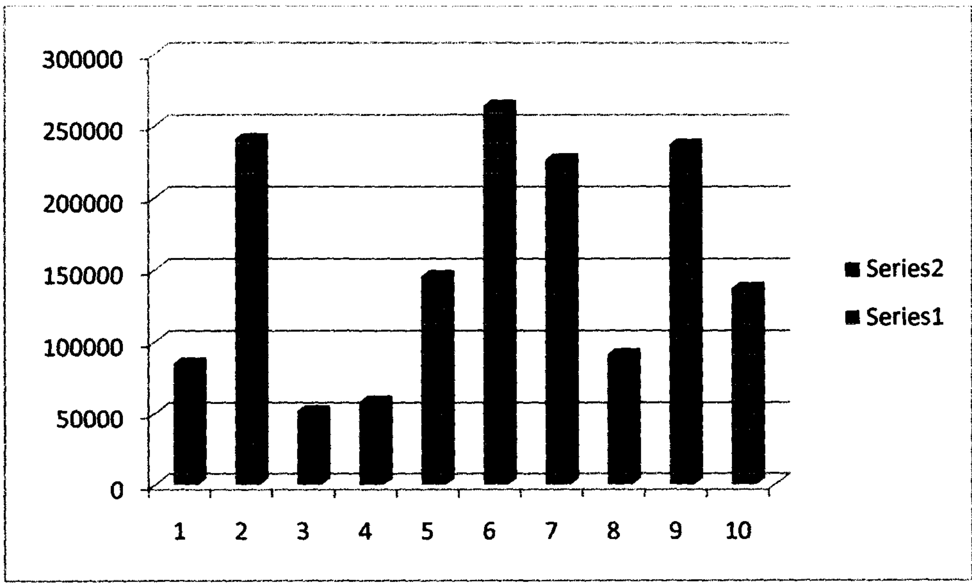

Fig 4.23 Bar Chart showing total cassava roots losses in each of the ten local government areas selected.

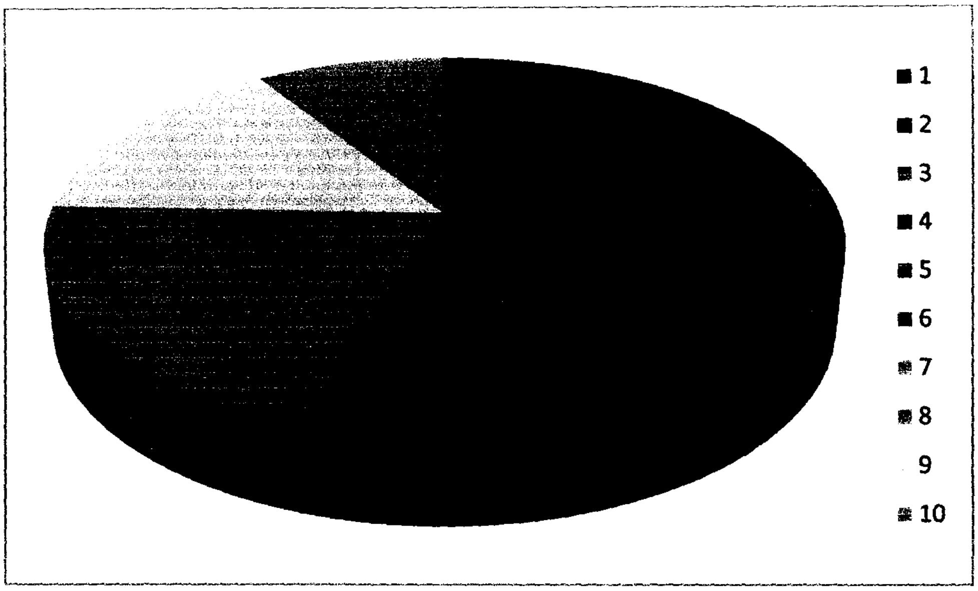

Fig 4.24 Pie Chart Showing Total Cassava Roots losses in Each of the Ten Local Government Areas Selected.

The percentage of the total cassava roots produced in all the ten local government area selected represented in the chart above are as follows; 6%, 16%, 3%, 4%, 9%, 17%, 15%, 6%, 15% and 9% respectively.

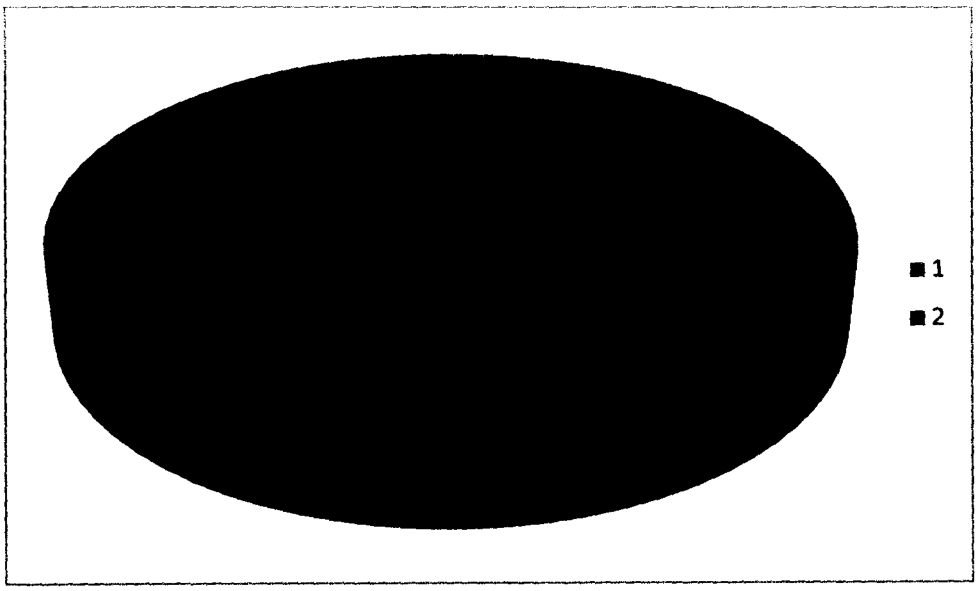

Fig 4.25 chart showing the total cassava roots produced and it losses to in all the ten local government areas

The above chart (fig 4.25) shows that the total losses in all the ten local government areas amount to 9%.

CHAPTER FIVE

5.0 Conclusion and Recommendations

5.1 Conclusion

Root crops, especially cassava is an important food crop and contributes significantly to the food availability to the people of kogi state and Nigeria as a whole. Recurrent adverse weather conditions have contributed to the increasing negative trend that these crops are going through. The crop estimates conducted by the kogi state ministry of agriculture do provide an indication of the availability of food per season. However, these figures are normally not accurate as crops losses are not seriously incorporated into the crop estimation process. This results in over-estimation in some seasons and under estimation in others. Major causes of crop losses in roots and tubers are pests such as cassava mealy bug, weevil, termites and green mite. Disease such as the cassava mosaic disease, cassava brown streak and cassava bacterial blight also do increase crop field losses while rotting, larger grain borer and cylas weevils are major causes of post-harvest losses of stored products. Crop losses vary from season to season and from one location to the other. As such, use of uniform figures across the seasons and location does not reflect accurate food availability. Crude methods of estimating crop losses are available although data from these methods are not used in the estimation of national estimates and food availability. Studies should be conducted to determine quantitative crop loss (pre- and post-harvest) estimates for each administrative or agro-ecological unit to improve estimation of food availability.

Having investigated and estimated the postharvest losses of cassava and method of improving its storage from the selected local government areas in the state, it was observed that postharvest losses of cassava is high and ways of storing it is little or no facility or knowledge of the method to use for storage. The postharvest losses of cassava in the selected local government area of kogi state is traced to have come from high production and low demand, and also lack of storage facilities and knowledge of storing it.

It is almost impossible to recommend a particular type of storage in all the ten local government areas covered but based on the findings or research carried out, it was found that the under ground method that is, not harvesting the cassava on time is the best method of storage as it is believed to last up to one season and the second one is to put fresh cassava in sawdust with about 45% moisture.

This work is hoped at arousing greater awareness of the importance of cassava storage in man's constant effort to obtain his primary need that is the supply of good quality food for himself without undue wastage.

5.2 Recommendations

In carrying out the study of this project, the researcher should first determine the number of farms to be covered and know the uniformity of the distribution and if possible, the study should commence immediately after harvest.

It is important that farmers should inculcate good maintenance culture of their various storage structures. This is achieved by a thorough cleaning of the store to remove all traces of the previous stored product. The dried roots should be well dried before storage and there should be an adequate system of monitoring the condition of the cassava during storage period.

Since cassava is almost not storable, the farmers, traders, processors and the consumers should adopt the following strategies to prevent rapid postharvest deterioration of the roots;

-FARMERS:

- Delay harvest;
- Traditional storage;
- Processing of roots into storable products;
- Processing of old unsold roots.

-TRADERS:

- Low quantities traded;
- High margins to compensate for risk;
- Buy standing crops;
- Highly integrated markets;
- Storage techniques (including traditional techniques and transferred technology);
- Processing of old unsold roots.

-PROCESSORS:

- Production and processing are in close proximity;
- Small-scale processing in rural areas;
- Processing into broad range of products (deed, fermented flours, starch, etc. for human consumption, industrial use and animal feed)
- Production for new export markets (e.g. Thailand).

-CONSUMERS:

- Substitute fresh cassava with processed foods and cereals unless cheap fresh roots are readily available;
- Improved storage techniques, such as refrigeration.

REFRENCES

Affran, D.K. 1968. Cassava and its economic importance. Ghana Farmer, 12(4): 172-178.

AFFRAN, D. K. 1968. Cassava and its economic importance. *Ghana Farmer,* **12**, 172-178.

Ajisegiri E.S.A. and Igbeka J.C (September, 1986:) Appropriate grain storage structure for Tropical use. A paper No. NSAE 26 presented at the Nigeria society of Agricultural Engineers National Conference at Ile-Ife.

Bai, K B.V. 1987. Recent advances in cassava genetics and cytogenetics. In: C. Hershey, ed. Cassava breeding: a multidisciplinary review pp. I -24. Cali, Colombia, CIAT.

Balagopalan, C., Padmaja, G., Panda, S.K. & Moorthy, S.N. 1988. Cassava in food, feed and industry Boca Raton, Fl., USA, CRC Press Incorporated.

Becker-Andre, M., Schulze-Lefert, P. & Hahlbrock, K. 1 991. Structural comparison, modes of expression and putative cis-acting elements of the two 4-coumarate: coenzyme A ligase genes in potato. J. Biol. Chem., 266: 8551 -8559.

Beeching, J., Dodge, A., Moore, K. & Rickard, J.E. 1994. Physiological deterioration in cassava: possibility for its control. Trop. Sci. (in press)

Benfey, P.N. & Chua, N.H. 1990. The cauliflower mosaic virus 35S promoter: combinatorial regulation of transcription in plants. Sci., 250: 959-966.

BOOTH, R. H. 1976. Storage of fresh cassava *(Manihot esculenta).* I. Post-harvest deterioration and its control. *Expl. Agric.,* **12,** 103-111.

Booth, R.H. 1978. A review of root rot diseases in cassava. In: T. Brekelbaum, A. Bellotii & J.C. Lozano, eds. Proceedings of the Cassava Protection Workshop. Cali, Colombia, November 1977. Cali, Colombia, CIAT.

Bottema, J.W.T. & Henry, G. 1990. History, current status and potential of cassava use in Asia. In: R. Howeler, ed. Cassava breeding, agronomy and utilization research in Asia, pp. 3-26. Bangkok, Thailand, CIAT.

Cabral, G.B., Aragao, FJ.L., Matsumoto, K., Monte-Neshich, D.C. & Rech, E.L. 1993. Cassava tissue culture: multiple shoots and somatic embryogenesis. In: W.M. Roca & A.M. Thro, eds. Proceedings of the First International Scientific Meeting of the Cassava Biotechnology Network, Cartagena, Colombia, August 1992.

CASSAVA NEWSLETTER, 1992. Trends in World Cassava Production, 16, p. 1.

Christou, P., McCabe, D.E., Martinell, B.J. & Swain, W.F. 1990. Soybean genetic engineering: commercial production of transgenic plants. Trends in Biotechnology, 8: 145-151.

Chuzel, G. 1991. Cassava starch: current and potential use in Latin America. Cassava Newsletter, 15(1): 9-1 1.

CIAT. 1987. Global cassava research and development. The cassava economy of Asia: adapting to economic change. Documentation of cassava demand studies conducted in Asia in collaboration with national programmes. Draft version prepared for the Technical Advisory Committee for the Nairobi meeting, June 1987. Cali, Colombia, CIAT.

CIAT. 1993. Cassava Programme, annual report 1992. Cali, Colombia, CIAT. (in press)

Cock, J.H. 1985. Cassava: new potential for a neglected crop. London, Westview Press.

Conkling, M.A., Cheng, C.I., Yamamoto, Y.T. & Goodman, H.M. 1990. Isolation of transcriptionally regulated root-specific genes from tobacco. Plant Physiol., 93: 12031211.

Coursey, D.G. & Booth, R.H. 1977. Post-harvest problems of non-grain staples. Acta Horticulturae, 53: 23-33.

Dendy, D.A.V. & Trotter, B.W. 1988. Wheatless and composite breads: technologies awaiting adoption. Entwicklung und Laendlicher Raum (Frankfurt am Main), 88(6): 1318.

Dietrich, A., Mayer, J.E. & Hahlbrock, K. 1990. Fungal elicitor triggers rapid, transient and specific protein phosphorylation in parsley cell suspension cultures. J. Biol. Chem., 265: 6360-6368.

Dixon, R.A. & Harrison, M.J. I 990. Activation, structure and organization of genes involved in microbial defence in plants. Advan. Genet., 28: 165-234.

Ekundayo, J.A. & Daniel, T.M. 1973. Cassava rot and its control. Transactions of the British Mycological Society, 61: 27-32.

Falcon, W.O., Jones, W.O., Pearson, S.R. et al. 1984. The cassava economy of Java. Stanford, Cal. USA, Stanford University Press.

FAO.Fauquet, C., Schopke, C., Chavarriaga, P., Sangare, A. & Beachy, R.N. 1993. Genetic engineering technologies to control viruses and their application to cassava viruses. In: W.M. Roca & A.M. Thro, eds. Proceedings of the First International Scientific Meeting of the Cassava Biotechnology Network Cartagena, Colombia, August 1992. Working Document 123. Cali, Colombia, CIAT.

FAO, 1994. African experience in the improvement of post-harvest techniques. Workshop in Accra, 4-8 July, 1994 Ghana, 85 pp.

FAO Training Series, FAD/UN 1985. Prevention of post-harvest food losses: A training manual. Rome.

Gulick, P., Hershey, C. & Esquinas-Alcazar, J. 1983. Genetic resources of cassava and wild relatives. Rome, International Board for Plant Genetic Resources.

Hahn. S.K., Terry. E.R. & Leuschner. K. 1980. Breeding cassava for resistance to cassava mosaic disease Euphytica. 29: 673-683

Hahn. S.K., Terry. E.R., Leuschner, K.,Akobundo. I.O., Okoli, C. & Lal, R. 1979. Cassava improvement in Africa Field Crops Research. 2: 193-226

Henry. G. 1991 Adoption of cassava technologies: constraints. strategies and impact. In: G. Henry. ed. Trends in CIAT commodities 1991. pp 22-40 Working Document 93 Cali. Colombia.CIAT

Iglesias. C. & Hershey. C. 1993. Cassava breeding at CIAT: heritability estimates and genetic progress throughout the 1980s. In: Proceedings of the Ninth Symposium of the International Society of Tropical Root Crops. IITA. Accra. Ghana. (in press)

Janssen. W. & Wheatley. C.1985. Urban cassava markets: the impact of fresh root storage. Food Policy. 8: 265-277.

MOFA-GTZ. 1994. Survey on post-harvest systems of yams and cassava. Post-Harvest Project. Tamale. Ghana.

Noon. R.A. & Booth, R.H. 1977. Nature of post-harvest deterioration of cassava roots. Trans. B. Mycol. Soc.. 69: 287-290.

Ocampo. C.. Hershey. C., Iglesias. C. & Iwanaga. M. 1993. Esterase isozyme fingerprinting of the cassava germplasm collection held at CIAT. In: W.M. Roca & A.M. Thro, eds. Proceedings of the First International Scientific Meeting of the Cassava Biotechnology Network. Cartagena. Colombia. August 1992. Working Document 123. Cali. Colombia, CIAT.

Passam. H.C.. Read. S.J. & Rickard. J.E. 1976. Wound repair in yam tuber: physiological processes during repair. New Phytol.. 77: 325-331.

Plumbley, MA., Hughes, P.A. & Marriott, J. 1981. Studies on peroxidases and vascular discoloration in cassava root tissue. J. Sci. Food Agr., 32: 723-731.

Rickard, J.E. & Coursey, D.G. 1981. Cassava storage. Part 1: storage of fresh cassava roots. Trop. Sci., 23: 1-32.

Rickard, J., Wheatley, C. & Gilling, J. 1992. Report on visit to Ghana to assess potential for fresh cassava shelf-life extension technology. Chatham, UK, Natural Resources Institute. (internal document)

Wheatley, C.C. 1982. Studies on cassava (Manihot esculenta Crantz) root postharvest physiological deterioration. University of London. (Ph.D. Thesis)

Wheatley, C.C. 1989. Conservation of cassava roots in polyethelene bags. CIAT Study Guide 04SC-07.06. Cali, Colombia, CIAT.

Wheatley, C.C. & Schwabe, W.W. 1985. Scopeletin involvement in post-harvest physiological deterioration of cassava root (Manihot esculenta Crantz). J. Exper Bot, 36: 783-791.

FEDERAL UNIVERSITY OF TECHNOLOGY MINNA

DEPARTMENT OF AGRIC AND BIORESOURCE ENGINEERING

PROJECT ON ESTIMATION OF POSTHARVEST LOSSES OF CASSAVA AND METHOD OF IMPROVING ITS STORAGE

(QUESTIONNAIRE BY YUSUF F. O.)

LOCAL GOVERNMENT AREA____

PLEASE TICK THE ANSWER(S) WHERE APPROPRATE:

1. What is/are the main problem(s) concerning the farm and farm household?

   ▯ Capital

   ▯ Health

   ▯ Rainfall

   ▯ Soil fertility

   ▯ Storage problems

2. What is the size of your cassava plantation?

   ▯ Less than one acre

   ▯ One to five acres

   ▯ Five to ten acres

   ▯ Ten acres and above

3. How important is cassava in your area?

- ⍰ Very important
- ⍰ Important
- ⍰ Fairly important
- ⍰ Not important

4. How important is cassava in your family?

- ⍰ Subsistence crop
- ⍰ Semi-commercial crop
- ⍰ Cash crop only

5. How many farmers cultivate cassava in your area?

- ⍰ Very few
- ⍰ Some
- ⍰ Almost all

6. How would you describe the consumption of cassava in your area?

- ⍰ Very low
- ⍰ Low
- ⍰ Medium
- ⍰ Important
- ⍰ Very important

7. How long do you leave your cassava plant harvesting?

- 6 months to 9 months
- One season
- Two season
- More than two season.

8. What do you do with your cassava roots after harvest?

- Sell immediately
- Stored fresh
- Stored after dried
- Processed to other product to sell.

9. What changes did you observe over the years?

- Transportation means
- Production techniques
- Harvesting techniques
- processing techniques
- Storage method

10. Have you increased the production of cassava over the years?

- Yes
- No
- Intending to
- No plan to do so.

11. What is the most tedious work related to cassava?

☐ Uprooting

☐ Transporting

☐ Peeing

☐ Storing

☐ Others (specify)____

12. How do you store your cassava root?

☐ Fresh

☐ Dried

☐ Both

13. What quantity of cassava did you harvest last season?

____

14. What are the estimated losses encountered?

☐ On the field_________________________________

☐ During transportation________________________

☐ When stored________________________________

15 Where do you store fresh cassava produce?

____

16 Which method of storage (fresh) is best for you?

____

17. Where and how do you dry your cassava chips?

- ☐ Sun drying on the ground
- ☐ Artificial dry

18. How long do you dry your cassava chip?

- ☐ Days
- ☐ Weeks
- ☐ Months

19. How long do you store your cassava chips?

- ☐ Days
- ☐ Weeks
- ☐ Months

20. Where are the main problems encountered during the storage of cassava?

- ☐ Mould
- ☐ Insects
- ☐ Rodents
- ☐ Theft
- ☐ Others (specify)____

21. Where are the main problems encountered when drying cassava?

 Mould

 Insects

 Rodents

 Theft

 Others (specify)____

22. How many times do you check the stored produce during storage?

 Once in a while

 Every month

 Every week

 Daily

23. Do you apply any storage protectants to the stored produce?

 Yes (specify)____

 No

24. If you use chemicals, how do you apply it?

 Dipping

 Spraying

 Dusting

 Others (specify)____

25. How do you protect the cassava produce in the past?

____

26. How do you prevent storage losses?

____

27. How do you assess your storage losses in terms of severeness?

- Severe
- Moderate
- Negligible

28. How do you prepare your storage structure before the next storage season?

- Cleaning
- Repairing
- Other methods (specify)______________________________

29. What do you do with the small cassava roots after harvest?

- Consumption
- Sale
- Sale and consumption
- Left it in the farm and forget it

30. Where would you need assistance?

- Capital
- Storage facility
- Distribution
- Processing.