KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUAMSI

COLLEGE OF AGRICULTURE AND NATURAL RESOURCES

FACULTY OF AGRICULTURE

DEPARTMENT OF HORTICULTURE

THE EFFECT OF SOME STORAGE METHODS ON THE QUALITY AND SHELF-LIFE OF SOME CULTIVARS OF WHITE YAM (*Dioscorea rotundata*) VARIETY

BY

ADDAE ALPHONSE KWESI

JUNE, 2013

THE EFFECT OF SOME STORAGE METHODS ON THE QUALITY AND SHELF-LIFE OF SOME CULTIVARS OF WHITE YAM (*Dioscorea rotundata*) VARIETY

A THESIS SUBMITTED TO THE SCHOOL OF RESEARCH AND GRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTER OF PHYLOSOPHY IN POST HARVEST TECHNOLOGY

BY

ADDAE ALPHONSE KWESI

JUNE, 2013

DECLARATION

I hereby declare that, except for specific references which have been duly acknowledged, this project is the result of my own research and it has not been submitted either in part or whole for any other degree elsewhere.

Signature ………………………… ………………………………….

ADDAE ALPHONSE KWESI Date

(Student)

Signature…………………………… ………………………………….

DR. B. K. MAALEKUU Date

(Supervisor)

Signature…………………………… ………………………………….

DR. BEN BANFUL Date

(Head of Department)

DEDICATION

This thesis is first and foremost dedicated to the Glory of God Almighty who provided all the strength, knowledge and wisdom needed to carry me through, and to my lovely wards, wife for their support, inspiration and encouragement.

ACKNOWLEDGEMENTS

In writing this thesis, I have drawn a lot of inspiration from many individuals especially my lecturers in Kwame Nkrumah University of Science and Technology, Kumasi.

My sincerest thanks go to my project supervisor, Dr. Bonaventure Kissinger Maalekuu for his guidance, patience, constructive comments and useful suggestions that have been particularly helpful to me in coming out with the final write up.

I also owe many thanks and appreciation to Mr. Simpiney Clement for analysing data obtained from the research and proof-reading.

Finally, to all those who contributed in one way or the other to the success of this thesis, however their names could not be mentioned here I say, the word "Thank you" are quite familiar but at this particular moment, I utter them to you with deep sense of gratitude , your contributions are gratefully acknowledged

ABSTRACT

Yam (*Dioscorea spp*) plays a central role in the food economy in most West African countries especially Ghana. Production is seasonal yet, the consumption of the tuber is required over the whole year. Postharvest losses especially at storage is a major challenge. Hence, the study was to investigate and note the suitable storage method that would minimize losses incurred during storage in five farming communities in two major yam producing districts, Wenchi and Tain in the Brong Ahafo region of Ghana. A survey, storage and laboratory experiment were conducted to solicit for the pre-storage treatments applied to yam, methods adopted for storage and farmers knowledge on postharvest losses and study the effect of some factors that initiate and cause loss. Proximate analysis was also conducted on two selected cultivars during and after storage to determine the nutritional variation of White yam variety. The survey revealed, only few farmers (28%) apply agro-chemicals such as Benlate and Rizolex to their harvested tubers before storage. The commonest storage used by the respondents is the yam barn (60%). Burial (30%) and heaps on floor (10%) storage methods were also used depending on time of harvest. The respondents also estimated 1-30% as losses often incurred after harvest and in storage due to injuries (31%), pests (23%), weight loss (4%), sprout (21%) and decay (40%). The storage experiment conducted however showed sprouting to be that high (93%). The storage methods caused a significant reduction on the nutritional composition of the stored tubers. With the three storage methods (heaps on floor, yam barn and open sided) evaluated, the open sided storage performed best in minimising weight loss, sprouting, decay, pest damage and nutritional composition.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICE

CHAPTER ONE

1.0 INTRODUCTION

Yams (*Dioscorea spp*) are annual or perennial herbaceous climbing or trailing crop plants that produce edible underground tubers. They are native to tropical regions of the World. Yam is produced throughout the length and breadth of Ghana. Commercial production areas in Ghana include: Wenchi, Mampong, Ejura, Kintanpo, Atebubu, Yendi, Tamale, Bole, Wa, and Kete-Krachi (Twumasi, 1986).

Dioscorea rotundata (white yam) and *Dioscorea alata* (water yam) are noted as the most economical and popularly cultivated species of yam in Ghana due to their high yielding qualities. Also, *Dioscorea rotundata* is the most widely grown and preferred yam species in Ghana. A large number of white yam varieties exist with the popular cultivars in Ghana being Pona, Tela, Dente, Serwaa and Doben.

Yams are among the most important staple food crops in the world particularly in the tropical and sub-tropical countries (Okigbo and Ogbonnaya, 2006). In fact, yam plays a central role in the food economy in most West African Countries especially Ghana. Yam is a major source of energy in the daily diet of many people and as such crucial to food security in Ghana. Yam contributes more than 200 calories per person per day for more than 150 million people in West Africa (FAO, 2006). Although yam tubers are mostly used for their high content of carbohydrate, they also have high protein, minerals such as calcium, phosphorus, iron and vitamins B and C (Splittstoeser and Rhodes, 1973).

Yam is an extremely vital crop both in the domestic and international market. In fact, Ghana is the third largest producer of yam in the world and the largest exporter annually (FAO, 2006).

In tropical Africa, for that matter Ghana, yam cultivation and harvesting is seasonal. However, the consumption of the crop is normally spread over the whole year. The storage of yam is challenged by numerous problems and often beyond the average farmer's control.

In yam production, postharvest losses constitute a major problem to yam growers as well as yam dealers. It has been estimated by various authorities that 20-80% of harvested yams are lost after harvest. FAO (1998) estimated that an average of over 25% of the yams produced and harvested in Nigeria are lost in storage.

Although traditional storage methods are very popular among farmers in most farming communities in Ghana, the methods are very poor as they predispose and make a lot of fresh yam vulnerable to a great deal of heavy losses during storage. The traditional storage methods in fact, do not provide yams with the prerequisite condition of good ventilation and protection from the hot sun, rains, and activities of pest and decay organisms and hence, exposes them to heavy losses at storage. This necessitates the adoption of an appropriate storage technology to make the crop available for the whole year.

The major task therefore is to find a suitable storage method or technology to keep the excess harvest and make the crop available all year round.

Better storage of yams, which ensure availability and supply of yam throughout the year with excess yams taken off the market and re-introduced during the lean season when yam is scarce will account for good prices or higher profitability to the farmers and thus, improve their living standards. The study hence sort to focus on better storage conditions which extend and maintain the edible and marketable qualities and shelf-life of some white yam cultivars.

The objectives were to:

- identify some pre-storage treatments applied to yam by the farmers in Wenchi and Tain Districts,
- identify methods that are adopted by farmers in the Wenchi and Tain District for the storage of yams,
- document farmers knowledge on postharvest losses in yams during storage,
- determine the effect of some storage methods on the nutritional and marketable qualities as well as the shelf-life of some cultivars of white yam.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 BOTANICAL AND AGRONOMIC CHARACTERISTICS OF YAM

Yam belongs to the genus *Dioscorea* (family *Dioscoreaceae*). They are annual or perennial tuber–bearing and climbing plants with over 600 species in which only few are cultivated for food and medicine (IITA, 2006). Six species out of the over 600 species are actually cultivated for food in the tropics (Hahn *et al.*, 1987).

The six edible species of yam of economic importance are *D. rotundata, D. alata, D. cayenensis*, *D. bulbifera*, *D. dumetorum, and D. esculenta* (Hahn, 1995).

Yam is classified as a monocotyledon but shows features of some dicotyledonous plants. The leaves and sometimes spiny vine of yam, climb 6-12 metres high in order to penetrate the canopy of a forest. It branches there to form its aerial apparatus and flower. Under the ground, yam possesses a shallow fibrous root system which is concentrated within the top, 30cm of the soil (Onwueme, 1978).

When the plant is grown from a true seed, one or several tubers are incepted, which originate from the hypocotyls and which generally penetrate deep into the soil (Lawton and Lawton, 1969).

Economically, the most important part of the yam is its tuber. They can vary greatly in shape and size and makes manual harvesting difficult and has so far prevented any kind of mechanization in harvesting. Cultivated forms of yam mostly produce cylindrical tubers with a brownish periderm and a firm white flesh which can be very heterogeneous in size and weight. The outer part of the tuber forms several layers of cork which constitute effective protection from lesion, water loss and against the penetration of pathogens in the soil as well as in storage after harvest.

2.2 ORIGIN AND PRODUCTION OF YAM

The *Dioscorea rotundata* originated in West Africa whiles the *Dioscorea alata* originates in the Far East (Asia) and spread westwards. Yams are grown mainly in the tropics and sub-tropics. Most of the world production of yam is from Africa (about 96%) with Nigeria alone accounting for nearly75% of the world total production. West African countries contributed over 93% of the world total production of over 51.4 million tonnes in 2006 (FAO 2007). West and central Africa account for about 94% of the world production, Nigeria being the major producer. Ghana is the third largest producer in the world behind Nigeria and Cote d'ivoire yet the largest exporter annually. Although, yam is cultivated across the length and breadth of Ghana, major areas of commercial production include: Ejura, Mampong, Wenchi, Kintampo, Atebubu, Yendi, Tamale, Bole, Wa and Kete-Krachi (Twumasi, 1986).

2.3 IMPORTANCE OF YAM PRODUCTION

Yam is important for food, income generation, socio-cultural activities and use for medicinal purposes in many countries in West Africa (Nweke *et al.,* 1991; Degras, 1993; FAO, 2000).

2.3.1 Nutritional Importance

The role played by yam in the food economy in West Africa cannot be over emphasized. Yam contributes more than 200 calories per person per day for more than 150 million people in West Africa (FAO, 2006). It ranked first among 20 most important food and agricultural commodities in Ghana and Togo in 2005 (FAO, 2006) and regarded as the most nutritious of the tropical root crops (Wanasundera and Ravindran, 1994).Yam is an excellent source of carbohydrate (energy), minerals (such as phosphorus, calcium and iron), vitamins (A and C) and dietary fibre (Bradbury and Holloway, 1988). Yam is also a good source of protein. It contains approximately four times as much protein as cassava and is the only major root crop that exceeds rice in protein content in proportion to digestible energy (Bradbury and Holloway, 1988).

Yam may be boiled, baked, mashed, roasted or fried and eaten with stew made with vegetables, fish or meat. In West Africa, yam is often pounded into a thick paste (Fufu) after boiling and is eaten with soup or processed into flour; and the flour cooked in boiling water to make a paste called "Kokonte" or "Amala" eaten with soup or stew (Omonigho, 1988).

2.3.2 Medicinal Uses

Aside their high value as food source, some species of yam have been used medicinally to treat diseases like diabetes, heart disorders and for preventing hypercholemia (Undie and Akubue, 1986). Also, some species are known to contain steroidal saponin and spogenins which are precursors for cortisone used medically for the management of menopausal symptoms and treatment of arthritis and menstrual disorders (Konesaroff *et al.*, 2001). Other species of yam are cultivated for extraction of diaosgeanin, a female hormone precursor uses in the manufacture of contraceptive pills and sex hormones (Ulbricht *et al.,* 2002). Some yam species such as *D. piscatorum* have toxic properties that allow them to be used in the production of insecticides. An insecticide from *D. piscatorum* is used in controlling insect pests of rice in Malaysia. Extracts from *D. deltoidea* is used in the production of anti-lice shampoo in India (Coursey, 1967).

2.3.3 Income Provision

Yam production provides a great deal of finance to farmers since it stores relatively better than many tropical crops and as such, sold for good prices during the lean season. Tropical root and tuber crops such as cassava, yam, and cocoyam are important household food security and income generating crops in many African countries (AMCOST 2006; FAO 1998). Over 5 million people are said to depend on these crops for food, feeds and income. Thus, losses associated with these crops limit the potential income of the farmers, threaten food security and exacerbate conditions of poverty among rural households, whose income stream depends on the ability to store excess farm produce for a later date (Ntiokwana 1999 cited by Thamaga- Chitja *et al.,* 2004). In Ghana yam contributes about 13% of household food budget in urban centres (Aidoo *et al.,* 2009). Yam is important in the local commerce in West Africa and accounts for about 32% of farm income (Chukwu and Ikwelle, 2000). The crop also serve as a major source of foreign exchange earnings and as the leading exporter of yam in the world, yam exports contribute significant foreign exchange earning to the Ghanaian economy (Ohene-Yankyera *et al.,* 2011). Yam is again used as raw material for starch industries and pharmaceutical companies and provide employment for a great number of people (Amanze *et al.*, 2011). The entire production, processing and marketing chain of yam offers a vast employment opportunities for millions of people. The supply of yam creates prospects for income generation due to the number of people involved and the value attached to it. The marketing system, which affect the price received by farmer and those paid by buyer, has a profound impact on sustainable food security (FAO, 2003).

2.3.4 Socio-cultural Importance

Yam is one of the most highly regarded staple food product in tropical countries of West Africa and are closely integrated into the economic, socio- cultural and religious aspects of life in the communities (Okigbo and Ogbonnya, 2006).

The ritual ceremonies and superstition often surrounding yam and its utilization in West Africa is a strong indication of the antiquity of uses of the crop (Norman *et al.*, 1995). New yam festival such as Homowo, Hogbetsotso are traditional ceremonies in Ghana that still accompany yam production, an indication of the high status given to the crop.

2.4 CONSTRAINTS TO YAM PRODUCTION

The major constraints to yam production include, non-availability and cost of planting materials, pests and diseases, weeds, cost of labour and storage losses (Wilson, 1982; Degras, 1993).

2.4.1 Storage Losses

In tropical Africa, yam cultivation and harvesting is seasonal. However, the consumption of the crop is normally spread over the whole year. The storage of yam however is faced with numerous problems. Post-harvest storage losses have been of concern and that, problems of storage of yam should be looked at more seriously.

During storage period, a substantial amount of yam is lost. Some of these losses are endogenous, that is physiological and include transpiration, respiration, and sprouting. Other losses are caused by exogenous factors like insects, nematodes, rodents, rot bacteria and fungi on the stored products (Wilson, 1980). Good management practices could help control the exogenous loss factors.

2.5 CONDITIONS NECESSARY FOR GOOD STORAGE OF YAM

Three main conditions are necessary for successful yam storage. These include: aeration, reduction of temperature and regular inspection of produce.

Ventilation prevents moisture condensation on the tuber surface and assists in removing the heat of respiration. Low temperature is necessary to reduce losses from respiration, sprouting and rotting. Regular inspections of tubers is important to remove sprouts, rotted yam tubers and monitor the presence of rodents and other pests. The storage environment must inhibit the onset of sprouting which increases the rate of loss of dry matter and subsequent shrivel and rotting of tuber. Good storage should therefore maintain tubers in their most edible and marketable condition by preventing large moisture losses, spoilage by pathogens, attack by insects and animals, and sprout growth (Osunde, 2008). In order to obtain good quality tubers after storage (that is fresh, edible and marketable yams), the freshly harvested yams to be stored must be clean and undamaged. Also, excessive temperature must be avoided and good aeration provided.

Weight loss is one of the severest indications of yam tuber deterioration which may be due to deleterious reactions (Osuji and Umezurike, 1985). Other reactions that result to deterioration may be due to protein hydrolysis and disintegration of the membranes of the tuber. Weight losses result from respiration (largely due to the oxidation of stored starch), desiccation and sprouting. Up to 35% of the total weight loss at 25ºC may be due to respiration during sprouting and up to 30% immediately after harvest (Ikediobi, 1985). Coursey and Walker (1960) had earlier shown that about 10% of the dry matter of tubers could be lost through respiration over a five (5) month period while dehydration could account for up to 20% weight loss for the same period.

2.6 STORAGE SYSTEMS

Varied systems of storage have been developed in West Africa, the centre for yam cultivation. FAO (1990) reported that, the choice of storage structure are influenced by the type of materials available and the resources on the farm, in particular the availability of labour and capital.

Storage systems widespread in West Africa include:

- Leaving the yam tubers in the mound after maturity
- Storing the yam tubers in trench silos
- Storage of yam tubers in heaps on the ground covered with straw or dry vegetative materials

- Storage of yam tubers in mud huts,
- Storage of yam tubers in yam barns (Opara, 1999).

2.6.1 Leaving Yam tubers in Mound after Maturity

This storage technique is occasionally considered by rural small-scale farmers, leaving the tubers in the mound after physiological maturity. When carried out on-farm, this type of storage prevents the use of the farmland for further cropping.

2.6.2 Storing the Yam Tubers in Trench Silos.

A typical storage facility made in the fields is the trench silo. To make this, a pit approximately corresponding to the expected volume of yams to be harvested is excavated. The pit is lined with straw or similar material (Nwankiti, 1989). The tubers are then stored on the layer of straw either horizontally on top of each other or with the tip vertically downwards beside each other. It is covered with straw or similar materials. In some cases a layer of earth is also added. This type of storage system can mainly be found in regions with a pronounced dry season. The trench silo provides protection from respiration and transpiration weight losses of the tubers. A disadvantage is the lack of ventilation and the direct contact of the tubers. This causes the stored produce to become warm and thus promotes the formation of rot (Nwankiti, 1989). The contact existing between the tubers promotes the spread of rot within the silo. The closed structure of the trench silo does not allow regular checking of the produce stored. Apart from this, the silo offers good refuge for rodents which cause the corresponding damage to the stored produce (Onwueme, 1978).

2.6.3 Storage of Yam Tubers in Heaps on the Ground

With this method of storage, the yam tubers are piled on a carpet made of dead yam climbers into a heap. This normally happens under a tree providing shade and the heap is covered with maize or millet stalks or similar materials (FAO, 1990). This method of storage can be erected without any costs. The shady tree somewhat balances out the temperatures occurring throughout the day and provides certain protection against overheating of the produce. This storage is badly ventilated. When closed, the produce cannot be checked regularly. This promotes rapid spreading of rot which means that storage duration is strictly limited. The stored produce is also damaged by insects and rodents that hide within the store (Nwankiti, 1989).

2.6.4 Storage of Yam Tubers in Mud Huts

This type of storage is often encountered in the savannah areas of the yam belt that is, in regions with a pronounced dry season (Nwankiti, 1989). They have firm wall erected in the traditional mud style. The roof consists of grass or other plant materials. The construction is generally oriented to the particular regional architectural customs. The yam tubers are piled on top of each other in the hut. The mud hut provides very good protection from rain and direct sunlight. With the roof made out of plant materials, the mud hut construction evens out temperatures. The lack of ventilation and the piling of the yams are problems here. Both promote the formation of rot and the stored yams can only be checked with difficulty. To build the mud hut requires a relatively high input of capital and labour. However, the hut acknowledges this by having a low degree of maintenance need and a service life of 20 – 30 years (Ravindran and Wanasundera, 1992).

2.6.5 The Storage of Yam Tubers in the Yam Barn

This system of storage is the most widespread among traditional yam farmers in West Africa. Yam barn consists of vertically erected wooden posts of about 3 meters in length and set at a distance of 50 cm to each other. The vertical posts are stabilised by attaching horizontal posts to them. Frequently, trees which are still growing are integrated into the storage system for static reasons and also, to provide natural shade (Marthur and Kongsdal, 2003). The yam barn is erected in the open air and it is important that there is sufficient shade available. To provide this, a roof is sometimes made of palm leaves, or evergreens are used as natural shade. The barn has to be constructed in an airy spot so that the surplus humidity in the air occurring from respiration and transpiration of the tubers can be emitted. Sufficient ventilation also reduces the risk of the tubers heating and thus limits weight loss due to respiration and transpiration (Onwueme, 1978). The yam barn is a well-aerated storage system which is easy to check. Germs and rotting tubers are easily removed. This system shows no problems during the dry season. During the rainy season the high humidity however leads to rapid rotting of the tubers (Onwueme, 1978).

The construction of the yam barn for use over several years requires not only a high input of costs (wood for construction) but also of work. Repair work normally occurs annually. Putting the tubers into storage, that is tying each individual tuber up, is a great amount of work. The tubers are often injured during tying which promotes the formation of rot (Nwankiti, 1989). The traditionally open method of building provides no protection from insect pests or termites. Often no measures are taken to protect the produce from rodents. The yam tubers are tied above each other to the vertical posts - mostly using plant fibres–starting from the bottom. The farmers use a particular method of tying for this (Nwankiti, 1989).

2.7 CHEMICAL COMPOSITION

The chemical composition of yam is characterised by a high moisture content and dry matter. The dry matter is composed mainly of carbohydrate, vitamins as well as protein and minerals. Nutrient content varies with species and cooking procedure. Cooking with the peel intact helps retain vitamins. Table 2.1 shows the ranges of nutritional composition for white yams varieties.

Table 2.1: Nutritional value of yam (Nutrient in 100g of edible portion)

Nutrient	**Range**
Calories (kcal)	71 – 135
Moisture (%)	65 – 81
Protein (g)	1.4 – 3.5
Fat (g)	0.2 – 0.4
Carbohydrate (g)	16.4 – 31.8
Fibre (g)	0.40 – 10.0
Ash (g)	0.6 – 1.7
Calcium (mg)	12 – 69
Phosphorous (mg)	17 – 61
Iron (mg)	0.7 – 5.2
Sodium (mg)	8.0 – 12.00
Potassium (mg)	294 – 397.00
B-carotene (mg)	0.0 – 10.0
Thiamine (mg)	0.01 – 0.11
Riboflavin (mg)	0.01 – 0.04
Niacin (mg)	0.30 – 0.80
Ascorbic acid (mg)	4.00 – 18

Source (Osagie, 1992)

2.8 QUALITY CHANGES OF YAM TUBER DURING STORAGE

Causes of storage losses of yam tubers include sprouting, transpiration, respiration, rot due to mould and bacteriosis, insects, nematodes and mammals (Passam *et al*., 1978). Sprouting, transpiration and respiration are physiological activities which depend on the storage environment, mainly temperature and relative humidity. These physiological changes affect the internal composition of the tuber and result in destruction of edible material, which under normal storage conditions can often reach 10% after 3 months, and up to 25% after 5 months of storage.

Investigations on the biochemical changes in stored yam tubers have shown that changes in starch, sugars, and protein take place during long-term storage (Afoakwa and Sefa-Dedeh, 2001; Serge and Agbor-Egbe, 1996). A study of yam tuber (*D. dumetorum*) stored under ambient and cold room conditions showed a rapid drop in moisture and starch content and an increase in the total alcohol-soluble sugars and reducing sugars after 72 hours of storage (Afoakwa and Sefa-Dedeh, 2001).

The rate of decrease in moisture and starch content and the rate of increase in sugar level were higher in tubers stored at room temperature than those stored under cold room conditions. A similar trend was observed for *D. rotundata* cv. Oshei and *D. dumetorum* cv. Jakiri after 110 days of storage under ambient conditions, weight losses reached 31% in Oshei tubers and 35% in Jakiri due to sprouting and dehydration. Starch content decreased by approximately 3.5-4.5 g/100 g while sugar and fibre values increased slightly in both cultivars.

A study of the physical, chemical and sensory changes occurring in white yams *(Dioscorea rotundata)* and yellow yams *(Dioscorea cayenensis)* stored for 150 days in traditional barns showed losses in moisture, dry matter, crude protein and ascorbic acid after 120 days of storage (Onayemi and Idowu,1988). A similar study by (Osunde *et al.,* 2003) reported a 17-22% reduction in weight, 30-50% reduction in crude protein and 38-49 % increase in sugar content for two cultivars of white yams (*D rotundata)* stored in a barn. Generally, in stored tubers there is reduction in weight, crude protein, starch and mineral content while the sugar and fibre contents increase (Osunde and Orhevba, 2009).

Water loss from tubers continues during storage and is significantly greater in tubers infected with *Sphaerostilbe bradys* compared to healthy tubers (Adesiyan and Odihirin, 1975). Yam rots usually start at maturity in the field due to entry of wounds by rot-causing fungi or bacteria and progresses in storage. Regardless of the source of inoculum, most rot-inducing pathogens are unable to enter fleshy tissues except through open wounds. Tubers which are already attacked by rot pathogens when harvested are destroyed to a greater extent in storage. The rate at which this occurs depends upon the storage conditions (Osagie, 1992). Adeniji (1970) reported considerable reductions in rots caused by fungal organisms when tubers were stored in such a way that free air circulation was maintained, compared to stock piling them on the floor of a shed. Coursey (1981) demonstrated that, a temperature of 50^{o}C causes tubers to lose weight and rot much more quickly than those kept in shade.

Optimum storage conditions for fungal growth on yam were also reported to be 22-29^{o}C and 80% relative humidity and above (Ogundana *et al.*, 1970). These conditions must be prevented in storage facilities.

2.9 CAUSES OF STORAGE LOSSES

The major problems associated with the storage systems are the postharvest losses arising from the methods. The sources of storage losses include:

2.9.1 Rotting

Rotting is due mostly to the effect of fungi and bacteria. The importance of microbial rotting in causing storage losses lies in the entry of pathogens which occurs through wounds or cuts and natural openings on the surface of the tubers (Ogundana *et al*., 1970). Although great variations have been observed between varieties, loss in weight of 10-20% after only three months occur at storage, and 30-60% after six months are not unusual even for sound tubers, and even greater losses have been observed to occur if infection by rotting organisms occur (Booth,1974).

2.9.2 Economic Importance of Rot

Post-harvest losses account for a reduction of about 26% in world yam production (Coursey and Booth, 1972). Booth (1974) estimated annual post-harvest yam loss in West Africa to be as high as 5 million tonnes. Adesiyan and Odihirin (1975) reported that post-harvest losses of tubers could be as high as 80% in storage. Ikotun (1989) reported that, 25% of post-harvest losses of yam in storage are due to decays. Losses due to rots affect availability, food security and revenue of farmers and traders. To reduce post-harvest losses and increase yam availability and avoid large fluctuations in supply and, therefore price, good storage is required. Good storage should maintain tubers in their most edible and marketable conditions by preventing large moisture losses and spoilage by pathogens (Osagie, 1992; Amusa *et al.,* 2003).

2.9.3 Initiation of Rot

Rots of fleshy parts of plants develop as tissues are disintegrated by the action of microorganisms. Extra cellular enzymes are produced in advance of the bacterial cells or fungal hyphae of the attacking pathogens. The affected tubers become hydrotic and soft, turn brown, emit offensive odour and exhibits a sharp demarcation between a healthy intact tissue and a decay tissue. Fungal pathogens causing rots in yam often gain entry into tubers through wounds caused by insects, nematodes or poor handling before, during and after harvest (Amusa *et al.,* 2003; Ricci *et al.*, 1979). Morse *et al.,* (2000) reported that most of the yam rot induced by insect attacks are mainly due to storage beetles (*Coleoptera*), mealy bug (*Planococcus citri*) and scale insect (*Aspidiella hartii*) during storage. Controlling fungi and insects during storage is necessary to increase shelf life of yams.

2.9.4 Causal Agents of Yam Rot

Yams are subject to several diseases caused by viruses, bacteria and fungi. Fungi, however, are the major causes of post-harvest rots of yam tubers (Noon, 1978; Okigbo and Ikediugwu, 2000; Coursey, 1967). The major microorganisms causing rot diseases in yams include *Aspergillus flavus* Lark ex Fr., *Aspergillus niger* Van *Tiegh, Botryodiplodia theobromae* Pat, *Fusarium oxysporum* Schecht ex Fr., *Fusarium solani* (Mart.) Sacc., *Penicillium chrysogenum* Thom, *Rhizoctonia spp.*, *Penicillium* *oxalicum* Currie and Thom, *Trichoderma viride* Pers. ex S.F. Gray and *Rhizopus nodosus* N'amyslowski (Okigbo and Ikediugwu, 2002).

Nine fungal species including *Aspergillus flavus, Aspergillus niger*, *Botryodiplodia theobromae, Fusarium culmorum, Fusarium oxysporum, Fusarium spp.*, *Penicillium brevi-compactum*, *Penicillium spp*. and *Rhizopus stolonifer* and a bacterium, *Erwinia carotovora* were identified to be associated with yam tuber rots in Ghana (Aboagye-Nuamah *et al.*, 2005; Bernett and Hunter, 1972). Information regarding the role of bacteria in yam rot, however, is scanty (Osagie, 1992).

2.10 CATEGORIES OF YAM ROT

The storage diseases of yam can be categorized into three, based on the symptoms and the causal agents.

2.10.1 Dry Rot

Dry rot symptoms vary with varying colouration, depending on the invading pathogen. When tubers are infected with *Penicillium oxalicum* and *P. cyclopium*, the tubers turn brown and then become hard and dry, maintaining their integrity, except when the tissues were invaded by *Sphaerostilbe marcescens* (IITA, 1993). Tissues invaded by *S. marcescens* become covered with the greenish mycelia of the fungus. Tubers infected with *Aspergillus niger* and *A. tamari* turn brown with yellowish margin. *Rosellina bunodes* and *B. theobromae* have also been reported to cause dry black rots. Tubers infected by the two organisms first turn grey and then black. These tubers become pulverulent and break into small dry particles (IITA, 1993).

2.10.2 Soft Rot

Tubers infected by soft rot organisms often turn brown, soft and become wet due to rapid collapse of cell walls of tissues. Fungi associated with this type of rot are *Rhizopus* spp., *Mucor circinelloides*, *Sclerotium rolfsii*, *Rhizoctonia solani* and *Armillariella mellea* (Ikotun, 1989).

2.10.3 Wet Rot

Wet rot of yam tuber is characterized by the oozing of whitish fluid out of infected tissues when pressed. This symptom is usually associated with the bacterium, *Erwinia carotovora* (IITA, 1993; Amusa *et al*., 2003).

2.11 CONTROL OF YAM TUBER ROT

Yam disease control has been extensively studied and several measures have been recommended. These include the use of crop rotation, fallowing and planting of healthy materials and the destruction of infected crop cultivars (Osunde and Orhevba 2009; Ogundana *et al.*, 1970).

For post-harvest losses, the following control measures have been known to be effective in controlling rots:

- Minimizing physical damage of tubers during post-harvest operations or handling.
- If wounding cannot be entirely prevented, tubers may be placed in an environment favourable to rapid heal of wounds.

- Treatment of yam tubers with fungicides such as Benlate and Captan just after harvest. The boring beetle attack on shoot and tubers can be controlled by application of granular Diazinon and Carbofuran (Amusa *et al.,* 2003). Treatment of yam tubers with insecticide dust (Actellic 2% dust) will reduce insect pests attack and also ameliorate physical damages acquired during harvest, resulting in significantly fewer fungal lesions (Morse *et al.*, 2000).

- Processing of yam tubers into chips will go a long way to reduce fungal attack. Yam farmers in south western Nigeria have been processing one-third of their harvested yam tubers into chips or cubes which can be stored between six months and one year as a means of reducing post-harvest losses associated with yam storage (Amusa *et al*., 2003).

It has been reported that the most effective and desirable means of controlling field yam diseases is by the selection and planting of resistant cultivars (Nwakiti and Arene., 1987). Some biological control measures have been carried out, using microbes to control yam rot.

Okigbo and Ikediugwu (2000) showed that *Trichoderma viride* displaced the naturally occurring mycoflora on the surface of the yam tuber. This simple application of *Trichoderma viride* effectively controls the normal tuber surface mycoflora throughout six months' storage, greatly reducing rotting. Okigbo and Nmeka (2005) showed that extract of *Xylopia aethiopica* and *Zingiber officinale* controlled post-harvest yam rot. It has been reported that plants with fungicidal properties are very effective in inhibiting fungal growth in-vivo and in-vitro (Kuhn and Hargreaves, 1987; Ibrahim *et al*., 1987). *D. alata* and *D. tripetala* are among the plants with such properties (Khan *et al*., 2001).

2.12 RESPIRATION AND TEMPERATURE

Losses due to respiration are high in the tropics as a result of uncontrolled temperature conditions, just as it has been established that the rate of respiration is dependent upon temperature (Booth, 1974). Roots and tubers are living organisms and as such, they respire. For respiration to occur freely, a supply of oxygen is needed and the resulting carbon dioxide and heat have to be removed from the products' environment. A limited supply of oxygen and inadequate removal of carbon dioxide may lead to effective asphyxiation and the death of product tissue (FAO, 1998). Excessively high temperatures may induce black heart, a disorder caused by the asphyxiation of the central cells (Booth and Proctor, 1972); and it is thought to occur in yams, where it has been shown that the internal temperature of tubers exposed to the sun may reach 45-50°C (Coursey, 1967). The respiration rate of yam tubers during storage have been observed to decrease with decreasing temperature over the range 30-50°C (Coursey *et al.,* 1966).

2.13 SPROUTING

A physiological cause of storage losses in yams is sprouting. This is the conversion of edible tuber material to inedible sprout and is considered a postharvest loss. Coursey (1981) showed that while sprouting of yams stored in different regions of Nigeria was very variable, it could reach 100% after 4 months' storage. Sprouting usually increases with increasing storage temperature up to a certain maximum (Booth, 1974). The storage life of yam tubers is finally terminated by the breakage of dormancy and subsequent sprouting (Coursey, 1981). Traditional practice normally involves breaking off the emergent sprouts when they are twenty or thirty mm long, unless the tubers are needed for planting. Further sprout development is delayed; the shelf life is extended by a few weeks and respiratory weight loss is reduced.

2.14 PESTS

Post-harvest and storage losses are also caused by pests, which include: insects, nematodes and mammals. Estimates of storage losses of roots and tubers due to insects are very scarce. Insects damage roots and tubers in two ways: by boring holes in the tubers, reducing the quantity and quality of the produce and sometimes the germination capacity; and by damage to the epidermis providing entry for moulds and bacteria to penetrate the tuber (FAO, 1998).

Quantitative pathogenic losses result from the rapid and extensive breakdown of host tissues by microorganisms; while qualitative pathogenic losses are typically the result of blemish or surface diseases which render the produce less attractive and so reduce its market value (Booth, 1974).

CHAPTER THREE

3.0 MATERIAL AND METHODS

3.1 SURVEY

A survey was conducted to find out; pre-storage treatments applied to yam by farmers, methods adopted by farmers for the storage of yam and farmers' knowledge on postharvest losses during storage.

The survey was conducted in two major yam growing districts of Brong Ahafo region in Ghana. The districts included: Wenchi and Tain. The study communities were Hani, Nkyeraa, Nsawkaw, Seikwa and Subinso. Agriculture Extension Officers were consulted to help identify yam producing farmers in their respective communities.

To avoid selectivity bias, simple random sampling procedure was used for this survey. Fifty respondents each from the five yam producing communities were interviewed by using a structured questionnaire. The interview schedule was personally conducted by the researcher.

3.2 EXPERIMENTAL WORK

3.2.1 Location and Time of Experiment

Evaluation of the effect of some storage methods on the edible and marketable quality and the shelf-life of cultivars of white yam was conducted in Berekum in the Brong Ahafo region of Ghana. Berekum is located within the transitional zone. The study area has a bimodal rainfall regime - a major wet season from April to July and a minor wet season from September to November. The two wet season are separated by a dry spell in August. The dry season occurs between December and March. The experimental work lasted for 150days from 3rd November 2012 to 30th March 2013.

3.3 STORAGE STRUCTURES AS TREATMENT COMPONENT

Storage structures used for the study were prepared prior to the commencement of the research. The structures included: The traditional barn, Heaps on floor covered with litter and open-sided shelves store with rodent guards. The storage structures were erected in open air, where sufficient shade and ventilation was available.

3.3.1 Traditional Barn

The traditional barn was constructed using vertically erected wooden posts of 2 metres in length, set at 50cm to each other. The vertical posts were stabilized by attaching horizontal posts to them. The yam tubers were tied above each other to the vertical posts starting from the bottom (Plate 3.2).

3.3.2 Heaps on floor Covered with Litter

The storage of yam tubers in heaps on floor covered with litter was undertaken by pilling a carpet of litter on the ground and then yam tubers piled on the carpet. The heaps were subsequently covered with similar litter material (Plate 3.1).

Plate 3.1: Heap on floor storage method

Plate 3.2: Traditional barn

3.3.3 Open Sided Store

The open-sided shelves store was prepared using wooden boards. A 2x4 wooden boards were used for the frame of the structure. The roof and shelves were done using 1x9 wooden boards. The sides of the stores were sparsely closed using 1/2x3 boards. The store had 30cm rodent guards made of roofing sheet fitted on the legs of the stands. There were 30cm intervals between two shelves to allow for good packing of the tubers in the store (Plate 3.3).

3.3 EXPERIMENT DESIGN OF STUDY

A 3x2 factorial experimental design in a Randomized Complete Block Design was employed for the research with 3 replicates. Three storage methods (traditional yam barn, open sided storage and heap on floor) were applied on two cultivars of white yam (*Discorea rotundata*). Five tubers of each cultivar of the white yam variety: Pona and Tela, were assigned for each replicate. A total of 90 tubers were used for the study. Extra tubers of each of the two selected cultivars were kept at same storage conditions for destructive analysis.

Plate 3.3: Open sided storage method and structure

3.4 DATA COLLECTED

3.4.1 Weight Loss

The initial weight of the yam tubers were measured and recorded based on the treatments used using electronic balanced. Weight of tubers of the yam was subsequently measured fortnightly. Weight loss of yam tubers and a percentage changes in weight was then calculated.

3.4.2 Dry Matter

Dry Matter of Yam tubers was determined using electronic oven both at the beginning and the end of the experiment.

Dry Matter Determination:

100g from various sections - head, middle, tail from the representative sample of the two cultivars of white yam (Pona and Tela) were used. Each section was replicated three times for each cultivar. Further slicing into smaller sizes to facilitate oven drying was done. The samples were dried at 100˚c for 24 hrs. A further 30mins drying was done to ensure a constant weight.

Percentage dry matter was hence computed as:

$$\frac{Oven\ dry\ weight}{Fresh\ Weight} \times 100$$

3.4.3 Assessment of Decay

Decay of yam was assessed through visual observation of rot fortnightly during the experimental period. Rotten yam tubers were counted and recorded.

Percentage yam decay was calculated as:

$$\frac{Number\ of\ decayed\ tubers}{Total\ number\ of\ Tubers\ per\ treatment} \times 100$$

3.4.4 Assessment on Sprout

Visual observation of yam tubers was conducted fortnightly during the experimental period. Sprouted tubers were counted and recorded.

Percentage of sprouted yam tubers was calculated as:

$$\frac{Number\ of\ sprouted\ tubers}{Total\ number\ of\ Tubers\ per\ treatment} \times 100$$

3.4.5 Damage by Pests

General Appearance of yam tubers was made by means of visual assessment. Damage of yam tubers by pests- rodents, termites were undertaken fortnightly. Damaged tubers by pests were calculated and expressed in percentages.

Plate 3.4: Tubers of yam damaged by pests

3.6 PROXIMATE ANALYSIS

Proximate analysis was conducted on the stored yam tubers during the experimental period and at the end of the study to establish the effect the various storage methods had on the Ether Extract, Crude Fibre, Crude Protein, Ash, Carbohydrate and Moisture Content. This analysis was carried out at the Department of Crop and Soil Sciences, Kwame Nkrumah University of Science and Technology-Kumasi.

3.7 DATA ANALYSIS

The survey data collected was analysed using Statistical Package for Social Sciences (SPSS) - descriptive and inferential statistics. The descriptive statistics comprised the use of frequency distribution tables, percentages and arithmetic mean.

And data resulting from the studied parameters were subjected to analysis of variance using Statistix Student 9.0 and means were separated at least significant differences (Lsd) of 1 and 5 percent.

3.7.1 Data Transformation

Data on sprout, pest damage and weight loss were transformed using the square root transformation before subjected to data analysis. Thus the results in Tables 4.3, 4.4 and 4.5 are the transformed means and were quoted along with the untransformed means in percentages in the interpretation of the results and discussion for easy clarification.

CHAPTER FOUR

4.0 RESULTS

This chapter presents the findings of the study and report the responses of respondents; yam producers randomly selected. A total of 250 producers were interviewed to ascertain their background information, variety of yam produced and level of production, postharvest activities and storage techniques employed and the general knowledge on postharvest losses and control measures. It also contains results of proximate analysis. Essentially, this chapter outlines the analysis and findings of the study by presenting the data with graphs (bar and pie charts) and tables.

4.1 FIELD SURVEY

4.1.1 Background Information on Respondents

Data on the sex of the respondents showed that males dominated in the production of yam with 70% against 30% of the females (Figure 4.1). Their ages range from 30 years to 60 years and above. Majority of them (45% of respondents) were within the ages 40 – 49 years, followed by 27% (50 – 59 years), 23% (60 years and above) and the least, 5% in the age range of 30 – 39 years. Thus, 50% representing the age range of 30 – 49 years are youthful people who go into the production of yam (Figure 4.2).

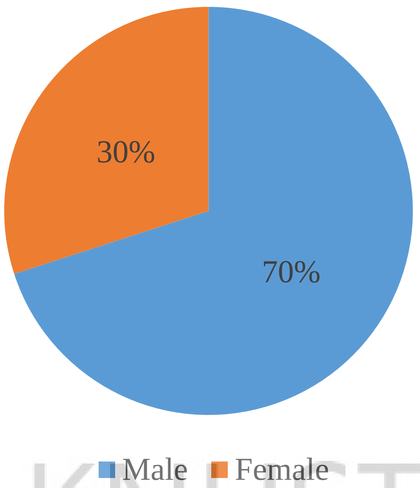

Figure 4.1: Sex of respondents

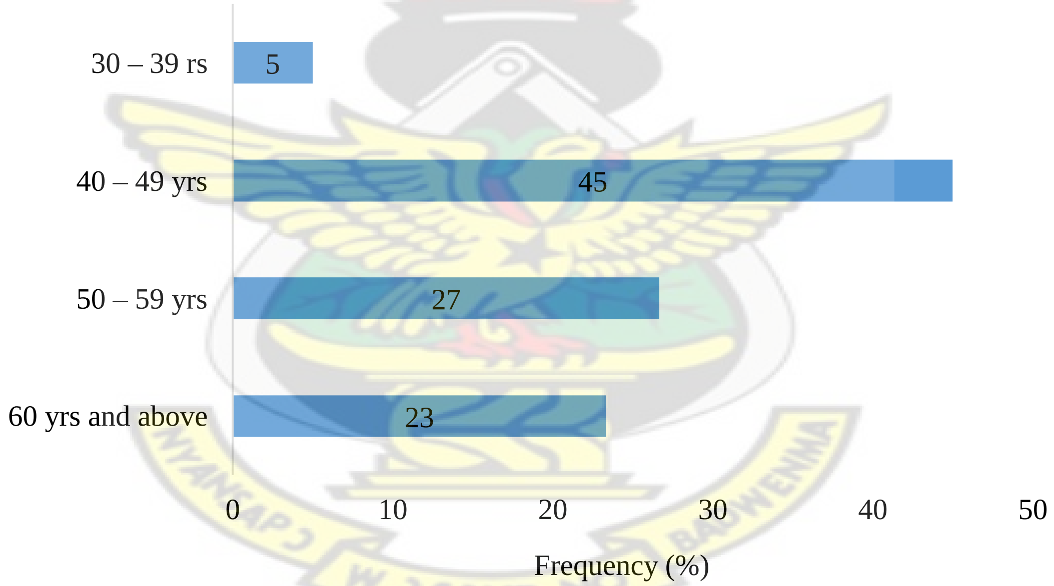

Figure 4.2: Age distribution of respondents

On the level of education, 12% had no formal education, 20% had basic education, majority of the producers interviewed had education up to the JHS level (58%), and only 10% had tertiary education. (Figure 4.3).

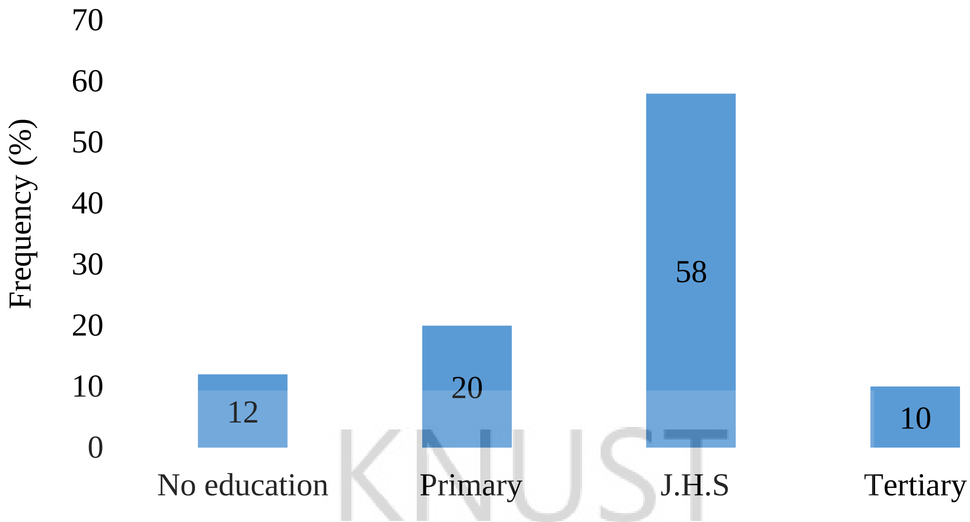

Figure 4.3: Educational background of respondents

4.1.2 Varieties of Yam Produced and Level of Production

4.1.2.1 Varieties of yam produced

The varieties of yam produced by the respondents were White yam and Water yam. Whereas 40% and 10% produced only white and water yams respectively, 50% of the producers prefer to produce both cultivars as seen in Figure 4.4.

With preference given to White yam, the producers cultivated four main cultivars of the White yam, namely: Tela (60%), Pona (20%), Doben (12%) and Dente (8%) (Table 4.1).

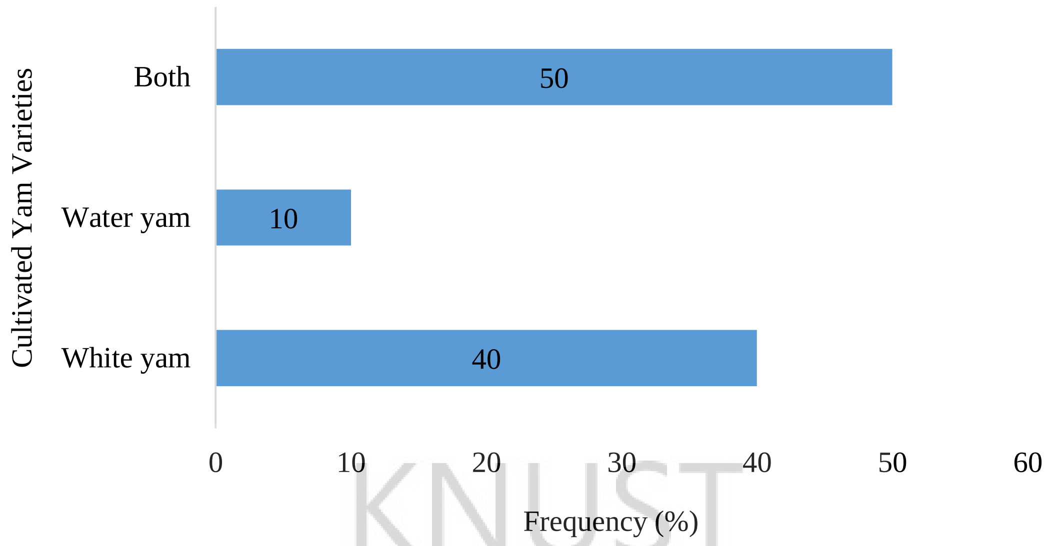

Figure 4.4: Types of Yam Cultivars produced by respondents

Table 4.1: Cultivars of White yam produced by respondents (farmers)

White yam cultivars	Frequency	Percentage
Pona	50	20
Tela	150	60
Doben	30	12
Dente	20	8
TOTAL	250	100

4.1.2.2 Level of production

A high number of the respondents are into commercial production (60%) whiles 40% are into subsistence (Figure 4.5). Seventy percent (70%) of interviewed producers are able to raise above 1000 mounds per production season, 20% 501 to 1000 mounds and 10% strive to raise 500 mounds or less in a season (Figure 4.6). It could be argued that respondents who raise 500 mounds or less are within the 40% of the producers who are into subsistence production.

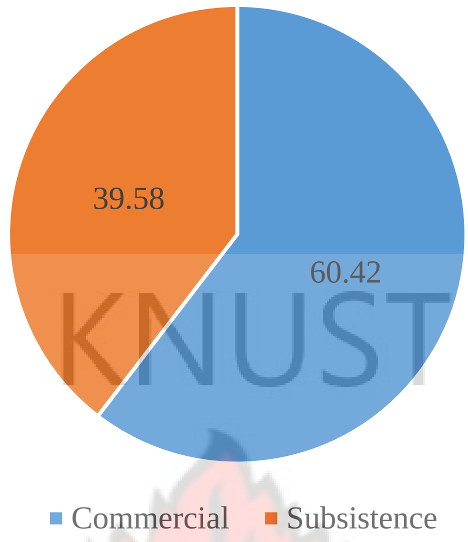

Figure 4.5: Type of farming practised by respondents

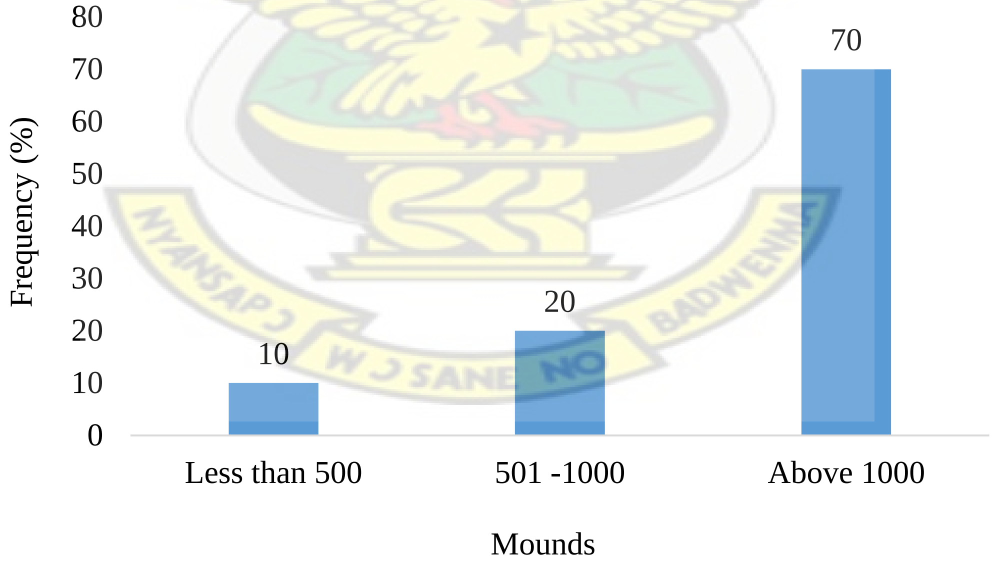

Figure 4.6: Number of mounds raised by respondents in a farming season

4.1.3 Postharvest Activities and storage Techniques Employed

4.1.3.1 Postharvest activities

The main activities employed by the yam producers were selling and storing harvested produce. The majority (60%) partly sold and stored their yam while 40% solely stored immediately after harvest. Generation of income is their main drive for sales. Reason for storage was partly to consume and sell for high price when there is scarcity of the produce.

A relatively low number of the producers applied agro-chemicals such as Benlate and Rizolex on yams as postharvest treatment before storage. Figure 4.8 shows 28% of the farmers did apply agrochemical on the yam while the majority (72%) of the farmers did no pre-treatment application before storing. Two factions of the producers argued that yam could store for more than (68%) or less (32%) for a period of 5 months (Figure 4.7).

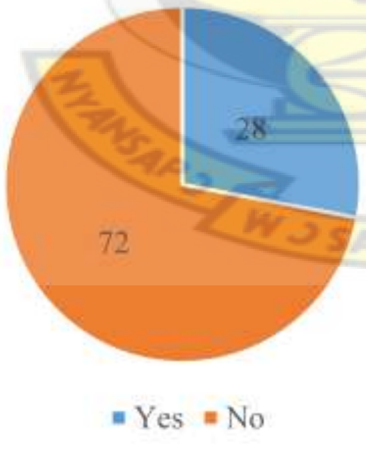

Figure 4.8: Farmers responds on the use of agro-chemicals as postharvest treatment

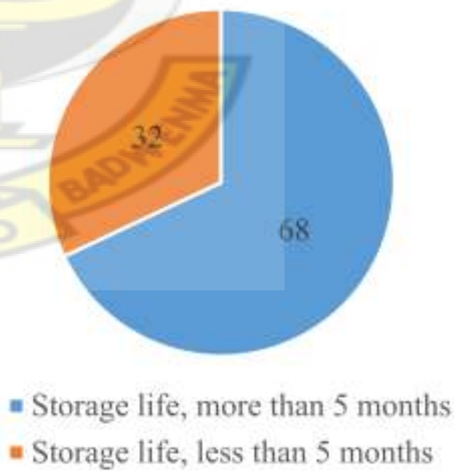

Figure 4.7: Farmers estimate on storage life of yam

4.1.3.2 Storage techniques employed

According to the farmers responses; 60% stored their yam in Barn, 30% stored by Burial method and 10% used the Heaps on Floor method of storage (Table 4.2). The farmers who use the respective method of storage reported that, Barn method stored the yam up to 5 months or more, the Burial and Heaps on Floor methods stored up to 3 months or more.

Table 4.2: Yam storage methods employed by farmers

Methods of storage	Frequency	Percentage
Barn	150	60
Burial	75	30
Heaps on floor	25	10
TOTAL	250	100

4.1.4 Postharvest Losses and Control Measures

4.1.4.1 Postharvest losses

The farmers (respondents) reported that, the postharvest losses incurred at transit and storage ranged between 1-30%. Forty (40) percent of the farmers suffer 11-20% losses. While majority (56%) of the producers incur a postharvest loss within a range of 1-10%, a few (4%) suffered a high loss of 21-30% (Figure 4.9).

They attributed the losses on their harvested produce to a number of contributing factors namely decay (40%), injuries (31%), pests (23%), weight loss (4%) and sprout (2%) (Figure 4.10).

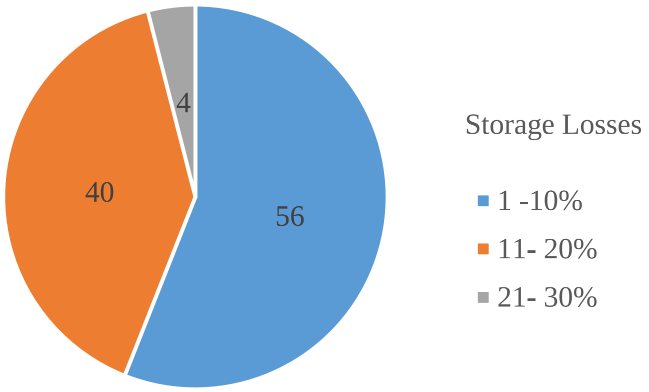

Figure 4.9: Percentage Losses at Storage

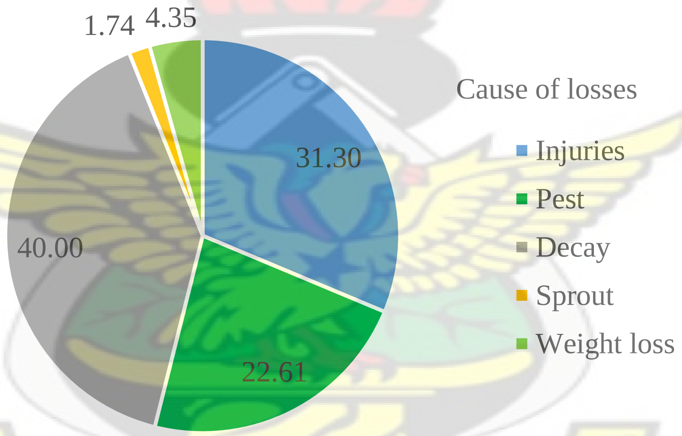

Figure 4.10: Farmers knowledge on the causes of Losses

4.1.4.2 Control Measures

Yam producers interviewed gave the account that, losses could be prevented and minimized by careful handling of harvested tubers during harvesting and transporting, pesticides use, clearing of bushes and traps would deter pests and rodents. They also believed that, decay and weight loss could be minimized by preventing injuries to tubers and shading respectively. Maintaining the edibility and marketability of stored yam is their major issue to address.

4.2.0 STORAGE EXPERIMENT

4.2.1 Individual Effect of Cultivar Variation and Storage Method on the Storage Life of White Yam

4.2.1.1 Cultivar effect on pest damage, weight loss and sprouting of white yam at storage

4.2.1.1.1 Pests attack

The result in Table 4.3 revealed the resistibility of Tela cultivar (0.00%) to pests/rodents attack throughout the storage period and was significantly different ($p<0.05$) from Pona (28.89%) which was prone to pest or rodent attack.

4.2.1.1.2 Weight loss

A significant difference ($p<0.05$) was recorded between the cultivars of which Pona and Tela had 21.12% and 25.95% weight loss respectively. Thus, Tela was more prone to weight loss (Table 4.3).

4.2.1.1.3 Sprouting

The two cultivars recorded a significant difference ($p<0.05$) against each other. Tela significantly recorded the highest number of sprout (77.78%) compared to Pona which had 55.56% sprout (Table 4.3).

Table 4.3: Effect of cultivar variation on pest damage, weight loss and sprout of White yam

Cultivar	Rodents Attack	Weight Loss	Sprout
Pona	1.31 a	4.64 b	1.79 b
Tela	0.71 b	5.12 a	2.10 a
Lsd (0.05)	0.12	0.46	0.26
CV	11.22	8.92	12.50

4.2.1.2 Storage method effect on pest damage, weight loss and sprouting of white yam at storage

4.2.1.2.1 Rodents attack

Open sided storage method performed best in putting pests and rodents into check. It recorded 0.71 (0.00%) pest attack. The traditional barn storage method 1.08 (16.67%) was significantly better ($p<0.05$) than the heap on floor storage method 1.24 (26.67%) which had the highest level of pest attack

4.2.1.2.2 Weight loss

The storage methods showed no significant effect ($p>0.05$) in reducing weight loss. Thus, they performed statistically equal in minimizing the weight loss among the stored tubers.

4.2.1.1.3 Sprouting

No significant effect ($p>0.05$) was seen among the three storage methods. Relatively, Traditional barn storage method 2.05 (73.33%) recorded the highest number of sprouted tubers, followed by heap on floor method 1.94 (66.67%) and open sided method 1.85 (60.00%).

Table 4.4: Effect of storage methods on pest damage, weight loss and sprout of White yam

Storage Methods	Rodents Attack	Weight Loss	Sprout
Open sided	0.71 c	5.08 a	1.85 a
Traditional Barn	1.08 b	4.77 a	2.05 a
Heap on floor	1.24 a	4.79 a	1.94 a
Lsd	0.15	0.56	0.31
CV	11.22	8.92	12.50

4.2.2 Interaction Effect of Cultivar Variation and Storage Method of the Storage Life of White Yam

4.2.2.1 Rodents attack

The interaction effect of the cultivars and the storage methods showed a significant difference ($p<0.05$) on pest attack. Except for Pona, stored in traditional barn and by heaped on floor storage method, all other tubers showed no significant signs of pest or rodent attack of 0.71 (0.00%) in their respective storages. Pona tubers stored by heaped on floor method 1.77 (53.33%) suffered significantly, the highest pest attack compared to those in traditional barn 1.46 (33.33%) as indicated in Table 4.5.

4.2.2.2 Weight loss

No significant interaction effect ($p>0.05$) was recorded among the means on weight loss.

4.2.2.3 Sprouting

The interaction showed a difference ($p<0.05$) among the means. Tubers of Tela stored in traditional yam barn recorded significantly, the highest numbers of sprouted tubers 2.34 (93.33%) against the least, ranged from 1.76 – 1.86 (53.33 - 60%), seen among Pona stored using the storage methods. The rest of the interaction means were statistically not different from each other and against the highest and the least (Table 4.5).

Table 4.5: Interaction effect of cultivar and storage method on the pest damage, weight loss and sprout of White yam

Interaction	Rodents Attack	Weight Loss	Sprout
Open sided*Pona	0.71 c	4.82 ab	1.76 b
Open sided*Tela	0.71 c	5.33 a	1.93 ab
Traditional Barn*Pona	1.46 b	4.52 b	1.76 b
Traditional Barn*Tela	0.71 c	5.03 ab	2.34 a
Heap*Pona	1.77 a	4.57 ab	1.86 b
Heap*Tela	0.71 c	5.01 ab	2.03 ab
Lsd	0.21	0.79	0.44
CV	11.22	8.92	12.50

4.2.3 Level of decay incidence over the storage period

The three storage methods adopted for the experiment performed equally and suppressed the incidence of decay for 77 days (10 wks). From the 12th weeks(84 days) onwards, rot was recorded. The stored tubers economically lasted for 150 days (5 months). The open sided storage method achieved the best of results with the least percentage of decay (10%) recorded. Heap method of storage had the highest level of decayed tubers (26.67%) and was significantly different ($p<0.05$) from decay incidence in open sided method (Fig4.11).

Generally, none of the cultivars of the white yam va ure riety studied showed resistance to rot. They (Pona and Tela) were significantly not different ($p>0.05$) from each other. However, a relatively high incidence of rot was recorded among the Pona than Tela which had 22.22% and 13.33% of rot respectively.

No significant interaction effect ($p<0.05$) was seen between cultivar and the storage methods.

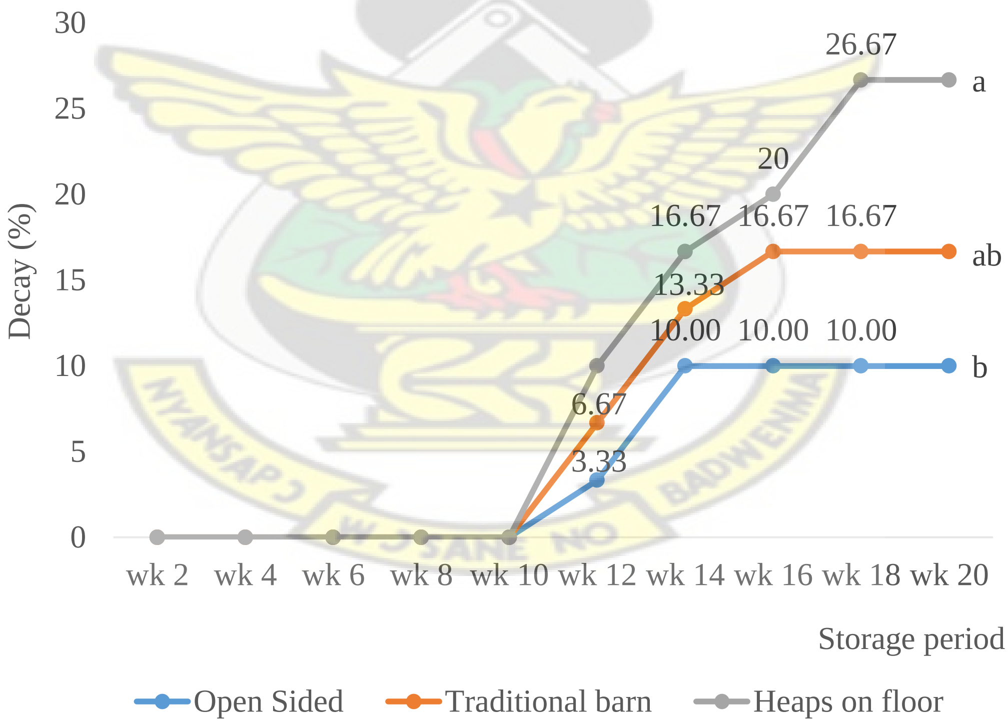

Figure 4.11: Effect of storage methods on the decay

4.3 PROXIMATE ANALYSIS

This part of the results gives an account on the effect of the storage methods on the nutritional composition of the two cultivars of white yam selected for the study. The analysis was done at the beginning and at the end of the storage experiment. The nutritional composition analysed comprise of the ash, carbohydrates, fat, fibre, moisture and protein content of the White yam.

4.3.1 Effect of Cultivar on Nutritional Composition of White Yam

Table 4.6: Cultivar effect on the nutritional composition of white yam at the beginning and end of the experiment

Cultivar	Fat		Fibre		Protein		Ash		Carbohydrate		Moisture	
	before	After	Before	after	before	After	before	after	before	After	before	After
Pona	1.00 b	0.98 a	2.18 b	2.07 a	5.30 a	5.23 a	2.17 a	1.91 a	91.87 a	89.17 b	69.34 a	67.24 a
Tela	1.17 a	1.06 a	2.33 a	2.40 a	5.06 b	5.01 b	1.83 a	1.82 a	91.72 a	89.38 a	58.81 b	56.64 b
Lsd (0.01)	0.02	0.09	0.02	0.36	0.02	0.01	1.07	0.36	0.71	0.02	0.03	0.02
CV	1.54	6.21	0.65	10.86	0.31	0.15	35.74	12.94	0.52	0.02	0.03	0.02

4.3.1.1 Fat content

Fat was significantly different ($p<0.01$) in both cultivars at the beginning of storage. Tela had a higher fat (1.17%) than Pona (1.00%). The fat was similar ($p>0.01$) in the cultivars at the end of the experiment.

4.3.1.2 Fibre content

Similarly, fibre content of the cultivars at the beginning was significantly different ($p<0.01$) making Tela richer in fibre than Pona. Both cultivars at the end of experiment was significantly not different ($p>0.01$) in fibre.

4.3.1.3 Protein content

Pona is richer in protein (5.30%) and significantly different ($p<0.01$) from Tela (5.06%) at the beginning of the storage. The trend remained unchanged even at the end of the storage regardless of the losses as both recorded 5.23 and 5.01 percent respectively.

4.3.1.4 Ash content

The ash content in both cultivars was significantly not different ($p>0.1$) at both periods, beginning and at the end of the experiment.

4.3.1.5 Carbohydrate content

Both cultivars, Pona and Tela significantly had an equal carbohydrate content and was not different ($p>0.01$) at the beginning but the levels changed at the end of the experiment. Thus, Tela (89.38%) at the end retained significantly ($p<0.01$), a higher carbohydrates than Pona (89.17).

4.3.1.6 Moisture content

Pona (69.34%) was significantly higher in moisture than Tela (58.81) at $p<0.01$. The trend remained unchanged after storage. They recorded moisture content of 67.24 and 56.64 percent respectively.

4.3.2 Effect of Storage Methods on the Nutritional Composition of White yam

Table 4.7: Storage method effect on the nutritional composition of white yam at the beginning and end of the experiment8

Storage	Fat		Fibre		Protein		Ash		Carbohydrate		Moisture	
	before	After	before	after	before	after	before	after	before	After	before	After
Open Sided	1.00 b	0.98 b	3.30 a	3.07 a	5.19 a	5.15 a	1.75 a	1.85 ab	91.73 ab	90.68 a	67.41 a	65.94 a
Trad barn	1.00 b	0.98 b	1.53 c	1.61 b	5.19 a	5.12 b	1.50 a	1.58 b	92.32 a	89.21 b	61.56 c	58.12 c
Heaps	1.25 a	1.11 a	1.95 b	2.03 b	5.17 a	5.11 b	2.75 a	2.17 a	91.34 b	87.93 c	63.26 b	61.76 b
Lsd (0.01)	0.03	0.12	0.03	0.44	0.03	0.01	1.31	0.44	0.87	0.03	0.03	0.03
CV	1.54	6.21	0.65	10.86	0.31	0.15	35.74	12.94	0.52	0.02	0.03	0.02

4.3.2.1 Fat content

Tubers heaped on floor generally recorded the highest fat content (1.25%) and was significantly different from the open sided and traditional barn which influenced the same level of fat (1.00%) in the tubers. The same trend was seen at the end of the storage regardless loss in fat.

4.3.2.2 Fibre content

The fibre content in the yam tubers under the various storage method was significantly different ($p<0.01$). In order of decreasing, yam tubers stored in open sided structure had the highest fibre content (3.30%), followed by heaps on floor (1.95%) and the least, traditional yam barn (1.53%).

The levels in the tubers changed slightly with heaps on floor (2.03%) and traditional yam barn (1.61%) influencing an increased in fibre at the end of storage. They were significantly not different from each other. The open sided storage method however caused the tubers to make a lost in fibre which significantly different ($p<0.01$) and still was highest (3.07%).

4.3.2.3 Protein content

The level of protein in the yam tubers at the beginning of the storage influenced by the various storage methods was significantly equal ($p>0.01$).

A marginal lost in the protein occurred in the tubers at end of storage. The open sided method performed better in maintaining a significant level of protein higher (5.15%) and different from traditional yam barn (5.12%) and heaps on floor (5.11%) which were not different.

4.3.2.4 Ash content

Ash content of the yam tubers influenced by the storage methods at the beginning was significantly not different ($p>0.01$).

Regardless of an increase caused by the other storage methods, heaps on floor method performed better in maintaining a significant high ash content. It influenced the ash content of the stored tubers to 2.17%, different from those stored with the traditional yam barn (1.58%) at $p<0.01$. Open sided (1.85%) was significantly not different from neither of them.

4.3.2.5 Carbohydrate content

Whiles open sided method influenced an equal carbohydrate as compared to the other methods, the traditional yam barn at beginning had a significant impact on the yam tubers as it recorded the highest (92.32%) carbohydrate and the least, in those heaped on floor (91.34%).

Carbohydrate content influenced by the storage methods at the end of the experiment was significantly different ($p<0.01$). The open sided method recorded the highest (90.68%), followed by traditional barn (89.21%) and the least, heaps on floor (87.93%).

4.3.2.6 Moisture content

The moisture content of the yam tubers was influenced to a significantly different level both at the beginning and at the end of the experiment. The open sided storage did best in retaining significantly, the highest moisture content (65.94%), followed by heaps on floor (61.76%) and the least (58.12%), by the traditional yam barn. This was a similar trend recorded at the beginning of the experiment regardless of the losses.

4.3.3 Interaction Effect of Cultivar and Storage Method on the Nutritional Composition

Table 4.8: Interaction effect of cultivar × storage methods on the nutritional composition of white yam at the beginning and end of the experiment

Interaction	Fat		Fibre		Protein		Ash		Carbohydrate		Moisture	
	Before	after	before	after	Before	after	before	after	Before	After	before	after
Pona*Open Sided	1.00 b	0.98 b	3.08 b	2.54 b	5.69 a	5.64 b	1.50 b	1.61 b	91.81 ab	89.82 b	73.46 a	71.37 a
Pona*Traditional barn	1.00 b	0.97 b	1.53 d	1.60 c	4.64 d	4.55 f	1.50 b	1.58 b	92.86 a	89.63 c	66.34 c	63.55 c
Pona*Heaps on floor	1.00 b	0.98 b	1.94 c	2.07 bc	5.56 b	5.51 c	3.50 a	2.55 a	90.94 b	88.05 e	68.23 b	66.80 b
Tela*Open Sided	1.00 b	0.98 b	3.52 a	3.60 a	4.68 d	4.65 e	2.00 ab	2.09 ab	91.65 ab	91.54 a	61.37 d	60.50 d
Tela*Traditional barn	1.00 b	0.98 b	1.52 d	1.62 c	5.73 a	5.68 a	1.50 b	1.58 b	91.77 ab	88.78 d	56.78 f	52.68 f
Tela*Heaps on floor	1.50 a	1.23 a	1.96 c	1.99 bc	4.77 c	4.71 d	2.00 ab	1.79 b	91.73 ab	87.81 f	58.29 e	56.73 e
Lsd (0.01)	0.04	0.16	0.04	0.63	0.04	0.02	1.85	0.62	1.23	0.04	0.05	0.04
CV	1.54	6.21	0.65	10.86	0.31	0.15	35.74	12.94	0.52	0.02	0.03	0.02

4.3.3.1 Fat Content

The interaction of the cultivar and storage method showed a significant influence ($p<0.01$). Tubers of Tela stored by heaps on floor had fat content (1.50%) different from the rest of the tubers that had the same fat content (1.00%) irrespective of the cultivar and storage method at beginning of the experiment.

The fat reduced marginally by 0.02% and as high as 0.27% at the end of the experiment. Difference among interaction means remained unchanged. That is, the tubers stored in the various storage system showed no significant difference ($p>0.01$) in fat except Tela stored by heaps on floor method.

4.3.3.2 Fibre Content

The interaction showed a significant difference ($p<0.01$) in fibre content at the beginning of the experiment. Tubers of Tela, stored using the open sided storage method recorded significantly, the highest fibre content (3.52%) followed by Pona stored using open sided (3.08%), tubers of both cultivars heaped on floor which had 1.94% and 1.96% respectively but were not different from each other, and finally, Pona and tela stored in traditional barn (1.53 and 1.52 %) respectively but showed no difference).

At the end of the experiment, the interaction influenced a significant reduction in fibre except with Tela stored in open sided storage and by heap on floor method. This cultivar in its respective storage as mentioned earlier, had an increased from 3.52% to 3.60% and 1.96 to 1.99%.

4.3.3.3 Protein Content

The protein content of Tela and Pona at the beginning of the experiment in the open sided and traditional yam barn were richer in protein and recorded the highest crude protein of 5.73% and 5.69% respectively yet, were statistically equal. They were followed by 5.56% and 4.77% (Pona and Tela, heaped on floor respectively) which were significantly different ($p<0.01$). The least protein content were 4.68% and 4.64% (Tela and Pona stored in traditional yam barn and open sided respectively). Both showed no significant difference.

Irrespective of a lost recorded, the interaction showed a significant difference ($p<0.01$) after the storage period. In a decreasing order, Tela in traditional recorded the highest (5.68%), followed by Pona in open sided (5.64%), Pona stored by heap on floor with (5.51%), Tela heaped on the floor (4.71%), Tela in open sided (4.65%) and the least, Pona in traditional yam barn (4.55%).

4.3.3.4 Ash Content

Tubers of Pona heaped on floor significantly recorded the highest ash content (3.50) than the rest at the beginning of the storage except with Tela stored in open sided storage and heaped on floor (2.00). The rest were significantly not different ($p>0.01$).

The level of ash at the end, appreciated marginally in the two cultivars stored with the open sided and traditional yam barn methods. They were significantly not different ($p>0.01$) and similar to Tela heaped on floor. Regardless of the lost, the highest and the least ash content of 2.55% and 1.79% in Pona and Tela respectively was significant ($p<0.01$) and different when stored with the heap on floor method.

4.3.3.5 Carbohydrate Content

Except for Pona, stored in traditional barn and heaped on floor, the rest were significantly not different ($p>0.01$) from each other. They had carbohydrate content range from 91.65 to 91.81%. Pona in traditional barn recorded the highest carbohydrates (92.86%) different from Pona heaped on the floor which had the least (90.94%).

At the end of the experiment, carbohydrates in the two selected cultivars of the White yam were significantly different ($p<0.01$) when stored with the three storage methods. That is, the levels in the Pona and Tela were highly different from one another when stored with their respective storage methods. In the decreasing order, the highest was recorded by Tela in open sided (91.54%) followed by Pona in open sided (89.82%) and traditional barn (89.63%), Tela in traditional barn (88.78%) and then, Pona (88.05%) and the least, Tela (87.81%) stored by heaps on floor method.

4.3.3.6 Moisture Content

The interaction of the cultivar and storage method on the initial moisture content was highly significant ($p<0.01$) and the means, different from one another when compared. Pona stored in open sided storage recorded the highest amount of moisture content (73.46%), followed by 68.23% (Pona, heaped on floor), 66.34% (Pona, open sided), 61.37% (Tela, open sided), 58.29% (Tela, heaped on floor) and the least, 56.78% (Tela, traditional barn).

Similarly, the interaction remained highly significant ($p<0.01$) at the end of the storage period. The trend remained unchanged with the levels of moisture content in the two cultivars influenced by the storage methods. Thus, tubers of Pona stored in open sided, heaped on the floor and in traditional yam barn retained the highest level of moisture in the order, 71.37, 66.80 and 63.55 respectively. These were followed by Tela, in open sided (60.505), heaped on the floor (56.73%) and traditional yam barn (52.68%).

4.4 DRY MATTER

4.4.1 Interaction Effect of Storage Method and Cultivar on the Dry Matter Content of White Yam

Table 4.9: The interaction effect of cultivars and storage methods on the dry matter content of white yam at end of storage

Cultivar*Storage Interaction	Dry matter
Pona*Open sided	39.33 cd
Pona*Tradition barn	40.33 bc
Pona*Heaps on floor	38.33 d
Tela*Open sided	41.67 ab
Tela*Traditional barn	42.67 a
Tela*Heaps on floor	40.67 bc
Lsd (0.01)	1.95
CV	1.86

Table 4.9 showed a significant interaction effect ($p<0.01$) of the storage methods and the cultivars. Tubers of Tela stored in the traditional yam barn at the end of the storage period recorded significantly, the highest dry matter content (42.67g). The dry matter content of tubers of Tela, that were stored with open storage method, had 41.67g and was significantly different from 39.33g (Pona stored with Open sided storage) and 38.33g (Pona tubers heaped on the floor). However, it was not different from tubers of

Pona stored in the traditional barn (40.33), heaped on floor tubers (40.67g) of Tela and those in open sided storage (41.67g). The heaped on floor tubers of Pona which had the least dry matter content, was significantly different (p<0.01) from the tubers that had the highest interaction effect.

4.4.2 Individual Effect of Cultivar and Storage Method on the Dry Matter of White Yam after Storage

Table 4.10: The effect of cultivars and storage methods on the dry matter of white yam

Cultivars	Dry matter
Pona	39.33 b (32.67*)
Tela	41.67 a (34.67*)
Lsd (0.01)	1.12 (3.95*)
Storage Methods	
Open sided	40.50 ab
Traditional barn	41.50 a
heaps on floor	39.50 b
Lsd (0.01)	1.38
CV	1.86 (11.74*)

*Values in brackets marked by asterisk are the dry matter *means, Lsd and CV* of both cultivars before storage

The dry matter of the two selected cultivars of White yam, Pona (32.67g) and Tela (34.67g) before storage were statistically not different (p>0.01). However, both cultivars at the end of the storage, recorded a significant different (p<0.01) dry matter content. Tela naturally had the highest dry matter content (41.67g) than Pona (39.33g). This showed an impact of the storage on the tubers. The storage methods used acted differently ($p<0.01$) on the stored tubers in respect to dry matter content. Except for open sided storage method (40.50g) which had the same impact to the rests, traditional barn influenced significantly, the highest level (41.50g) of dry matter content than heap on floor method that had the least (39.50g) as indicated in Table 4.10.

4.5 COST BENEFIT ANALYSIS OF THE STORAGE STRUCTURES

The table below shows the cost and benefit of the storage structures used for the experiment. The analysis proved that open sided storage performed best with expected profit of GH¢70.00 regardless of the relatively high cost of GH¢200.00 incurred during the construction. Heaps on floor broke even whiles traditional barn yielded well with expected profit of GH¢40.00 per storage of every 30 tubers.

Table 4.11: Cost-benefit analysis of storage structures for the study

	ITEMS/STORAGE STRUCTURE	OPEN SIDED STORE	TRADITIONAL BARN	HEAPS ON FLOOR
1	Cost of Construction	GH¢100.00	GH¢40.00	GH¢30.00
2	Initial Cost of Tubers (30 per method)	GH¢90.00	GH¢90.00	GH¢90.00
3	Time Spent During Inspection and Data Collection	5hrs	15hrs	10hrs
4	Cost of labour per Time Spent	GH¢10.00	GH¢30.00	GH¢20.00
5	Losses Due to Decay and Pest Damage	3 Tubers	10 Tubers	16 Tubers
6	Wholesome Tubers Remaining at End of Storage	27 Tubers	20 Tubers	14 Tubers
7	Income from Sales of Remaining Tubers	GH¢270.00	GH¢200.00	GH¢140.00
*	TOTAL COST	GHc200.00	GH¢160.00	GH¢140.00
**	TOTAL INCOME	GH¢270.00	GH¢200.00	GH¢140.00
***	EXPECTED BENEFIT	GH¢70.00	GH¢40.00	GH¢00.00

***Expected Benefit = Total Income – Total Cost

CHAPTER FIVE

5.0 DISCUSSION

5.1 SURVEY

5.1.1 Background Information on the Respondents

The outcome of the survey revealed that, the males are the dominant working group in the production of the yam due the intensity of energy needed for such work. The economic active age group of the farmers were within 40-49 years. It can be said that, the youth have little interest in farming since they were the minor. The result also shows the majority might have fallen unto farming (yam) as option after not able to go beyond the Junior Secondary level (Junior High School). Only few of the respondents reached the tertiary.

5.1.2 Production Level

Of the many yam varieties, the respondents were into production of two main varieties namely; Water yam (*Dioscorea alata*) and Whiter yam (*Dioscorea rotundata*). For security wise, the majority cultivate both but preference is given to White yam if they go solo. The cultivars of the White yam which are mainly produced by these farmers (respondents) are Tela, Pona, Doben and Dente. Of these, Tela and Pona were the most ones cultivated especially Tela. Majority of the respondents were into commercial production and raises 1000 yam mounds and above per production season. After harvest, 60% of these farmers preferred to sell their produce for income whiles others (40%) stored to use and sell for high prices when there is scarcity.

5.1.3 Postharvest treatments and Storage Methods Employed

Minority of the respondents (28%) apply agro-chemicals on the yam tubers as pre-treatment measures before storage. Majority of them (68%) estimated the storage life yam to be 150 days (5 months).

Three storage methods; storage in traditional yam barns, burial storage method and heaps on floor were identified and used by the respondents for storing their harvested yams. The commonly used one is the yam barns and the least preferred was the by heaps on floor storage technique.

5.1.4 Respondents' Account on Postharvest Losses at Storage and Control Measures

The respondents estimated their postharvest losses to be within 1 - 30% which is incurred at transit and storage. They attributed the losses on their harvest at storage to decay, injuries, pests attack, weight loss and sprout. It was also pointed out that, decay was the main contributing factor.

Their concern in maintaining the edibility and marketability of stored yams have caused them to institute the following as control measures;

- ✓ Careful handling of harvested tubers at harvest and transit (thus, when transporting)
- ✓ Use of pesticides
- ✓ Clearing of bushes around storage facility and
- ✓ Setting of traps to deter rodents

5.2 STORAGE EXPERIMENT

5.2.1 Effect of Some Storage Methods on the Shelf Life of White Yam

5.2.1.1 Pests (Rodents) Damage

Rodent pests are also a root cause of wounds on the tubers and most often carries of rot pathogens which induce decay. The results revealed the resistivity of Tela to pests/rodents attack as it suffered no significant incidence of attack throughout the storage period with all storage methods employed for the studies. This resistivity could be as result of genetic quality of this particular cultivar of the white yam. Pona on the other hand, was prone to pests and rodent attack when heaped on the floor (53.33 %) and stored in the traditional yam barns (33.33%). According to Igbeka (1985), rodent pests frequently attack and feed on some of the harvested tubers stored in yam barns. The easy accessibility of the stored tubers to the rodent pests on floor caused the high percentage of the attacked tubers. However, open sided storage method was able to put the pests and rodents into check completely.

5.2.1.2 Weight Loss

Weight loss is one of the severest indications of yam tuber deterioration which may be due to deleterious reactions (Osuji and Umezurike, 1985). This is often due to excessive respiration (largely due to the oxidation of stored starch) of stored produces occurring as a result persistent high temperatures and hence, account for postharvest loss. It is positively correlated with loss of water or moisture within a produce as a result of transpiration. According to (Ikediobi and Oti, 1983), respiration, transpiration and sprouting are the factors responsible for weight loss. These processes in effect, affect the appearance and cause tubers to shrivel. Weight loss also affected the quality of the produce (yam tubers at storage), as often seen in fruits and leafy vegetables. The storage methods employed were not different in minimising weight loss but the interaction showed much weight loss of Tela stored using open sided method compared to Pona in traditional barn which suffered less weight loss. Generally, Pona at the end of experiment retained a significant high amount of moisture and only suffered a weight loss of 21.12% compared to Tela which lost much weight (25.95%).

5.2.1.3 Sprout

The result revealed sprouting as the major factor that contribute and account for losses of yam tubers at storage. Generally, sprouting was significantly high at storage and not different with all the storage methods (Table 4.5). Without any pre-storage treatment, it was difficult for sprouting to be controlled or minimized at storage. Mozie (1984) reported that, high rate of ventilation reduces the growth rate of vines in stored tubers. However, the study showed otherwise as sprouting was extremely high, especially with count in traditional yam barn, of which Tela recorded the highest number of sprouted tubers (93.33%). This was significantly different from Pona, which on average, recorded the least number of sprout and also under the same storage in the above. It is possible that, the tubers of Pona cultivar could have a long dormancy period. That is, the duration of natural dormancy fluctuate according to the variety of yam between 4-18 weeks (Knoth, 1993).

5.2.1.4 Decay

Decay is one of the main indicators of loss which often occur at transit and storage. It mainly occur through injuries to a produce which normally gives room for wound pathogen organisms to invade the tissues and hence, cause rot. Amusa *et al.* (2003) attributed such wounds to insect damages, nematodes attack and poor handling before, during and after harvest. Yam normally stored best in a cool, well-ventilated storage devoid from excessive high temperature and high relative humidity variations. The three storage methods adopted performed well and could suppressed incidence of decay for 77 days.

Decay was very high in tubers heaped on floor (26.67%) as a result of direct contact to either soil or leaves materials in the floor. Presence of rot pathogen in soil or on the leaves material on the storage area serves as a source that initial decay. Poor air circulation within the heaped yam aid in the build-up of heat and increase humidity as result of respiration. It hence induces spores germination and growth of pathogens.

Open sided storage method did best as it recorded the least level of rot (10%). This storage allows in enough ventilation and circulation of air and reduces heat build-up and high humidity level. The two studied cultivars of the White yam were all susceptible to decay and had no significant difference, likewise the interactions.

5.2.2 Effect of the Three Storage Methods on Nutritional composition of White Yam

Not much information have been reported on the nutritional composition of yam in Ghana but a lot of research have been done on yam in Nigeria and the nutritional composition have been reported. The results in Table 4.6, 4.7 and 4.8 showed a significant reduction in moisture, fat, protein and carbohydrate except for fibre and ash content of the White yam cultivar after five months of storage with the three storage methods. The nutritional compositions of the cultivars were within the range reported by Osagie (1992) even after storage (Table 2.1). The level of ash increased slightly in both cultivars stored with open sided and traditional yam barn. Likewise, the fibre content of Tela tubers increased when stored with the heaps on floor method and in open sided storage. This reported increase in ash and fibre after storage, was also observed on tubers of White yam variety stored in yam barns with different conditions by Osunde and Orhevba (2009).

It has been reported that, moisture and protein levels in stored yam tubers decreases with time (Ihekeronye and Ngoddy, 1985). This study showed a similar result with a decrease in moisture, protein, carbohydrate and fat content in tubers of Pona and Tela of the White yam variety that were stored with the storage methods. The reduction in moisture content and carbohydrate could be due to respiration, transpiration and sprouting of the tubers. These are physiological activity that is promoted by high temperature and high relative humidity of the storage environment (Passam *et al.,* 1978). Passam *et al.* (1978) further reported that, respiration result in a steady loss of carbohydrate in the form of carbon dioxide and water, while at the same time, transpiratory loss of water occurs.

Research has shown that, traces of tannins which are found in some immature tissues of *D. rotundata* (Osunde and Orhevba, 2009) form complexes with protein and limit their availability. Hence, it is possible that, the decrease in the protein is due to tannins. The result also reveals that, fat is generally low in yam as shown in Tables 4.6 and 4.7. This could have been due to the result of the high incidence of sprout development and growth, since reserved energy (fat and carbohydrate) and minerals are used for this physiological activity.

Tuber and root crops are rich in carbohydrates (Osunde and Orhevba, 2009). The tubers had a high level of the carbohydrates within the range reported by Osagie (1992). Generally, carbohydrate decreased slightly after the storage period in the three storage methods of which the levels were significantly different (Table 4.7). It is supported by Sahore *et al.* (2007) who report that, carbohydrate content of yam tuber decreases during storage due to conversion of starch to sugar and respiratory losses of sugar as carbon dioxide.

5.3 DRY MATTER CONTENT

The stored yams at the end of the storage period had an increased in the levels of dry matter content compared to the initial evaluation of dry matter of both cultivars. The storage methods used had a significant impact on the levels as they differed. The increase could be attributed to weight loss, influenced by some contributing factors such as harsh storage condition like high temperature and the tuber falling on the reserved nutrients and water in the case of sprouting and naturally physiological processes (respiration and transpiration) that goes on within the living tubers. And Osunde (2008) reported that, sprouting increases the rate of loss of dry matter and subsequently shrivel and cause rotting of tubers. The result on dry matter in Tables 4.9 and 4.10 showed otherwise. That is, an increased was seen. Coursey and Walker (1960) reported that, 10% of the dry matter of tubers could be lost through respiration over a five (5) month period while dehydration could account for up to 20% weight loss for the same period. However, the storage period lasted for five months.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

The study showed that sprouting was high and Pona tend to have a longer dormancy period than Tela cultivar. The traditional yam barn could not be seen as the best for storing Tela as 93% of the tubers got sprouted. The open sided performed quite well in minimizing sprouting of the stored tubers. Levels of decay among the cultivars were significantly equal. However, the open sided storage method did best in minimizing decay. No significant difference was recorded among the stored tubers with the various storage methods in terms of weight loss. Pona in general retained significantly, a higher weight than Tela.

The outcome of the study on pests/rodents attack revealed that, Tela cultivar is resistance to pests attack when stored with the three storage methods. Pona was only not attacked when stored with the open sided storage method. Hence, the open sided storage helped prevent pests/rodents attack.

There was a reduction in the nutritional composition of the two cultivars at the storage period. However, there were exceptions. The ash content of both cultivars increased slightly when stored with open sided and traditional yam barn. Tubers of Tela that were heaped on the floor at the end of the storage, recorded a slight increase in Fibre. Dry matter content of both cultivars increased at end of storage and was highly influenced by the traditional yam barn.

6.2 RECOMMENDATION

Based on the result of the study, open sided storage should be considered by producers of yams for storing their harvested tubers due to the facts that, it performed well in minimizing nutrient lost, weight loss and decay to considerable level and prevented pests/rodents attack. It also had a higher expected income of GH₵70.00 in comparison to the traditional barn (GH₵40.00) and heap on floor (GH₵0.00).

Open sided storage structure is durable if well-built, requires low degree of maintenance and provides good protection against rain and direct sunlight. It also promotes and enhances good ventilation, easy inspection of tubers, prevent and minimize rot due to pilling and injuries. Besides, local materials (plant materials such as wood and thatch) that are virtually free may be used for the construction.

In future metals should be considered for use as frames for the open sided store since they are stronger and long lasting as compared to the wood.

More over the environmental conditions such ambient temperature, relative humidity and the average wind speed around the storage structure should be considered in future for periodic monitoring to improve on this work.

REFERENCE

Aboagye-Nuamah, F., Offei, S.K., Cornelius, E.W. and Bancroft, R.D. (2005). Severity of spoilage storage rots of white yam (*Dioscorea rotundata* Poir). *Ann Appl Biol 147*: pp. 183-190.

Adeniji, M.O. (1970). Fungi associated with storage decay of yam in Nigeria. *Phytopathology 60*: pp. 590-92.

Adesiyan, S.O. and Odihirin, R.A. (1975). Histopathology studies of the yam tuber (*Dioscorea rotundata* Poir) infected with *Scutellonena bradys* (Steiner & Hettew). *International Biodeterioration Bulletin 11*: pp. 48-55.

Afoakwa, E. O. and Sefa-Dedeh, S. (2001). Chemical composition and quality changes occurring in *Dioscorea dumetorum* Pax tubers after harvest. *Food Chemistry 75*: pp. 85-91.

Aidoo, R., Ohene-Yankyera, K., Marfo, K. and Blaise, N.G. (2009). Patterns and determinants of yam consumption in a Ghanaian urban center: *Household demographics, income and gender Perspectives*; In: Securing livelihoods through yams, Proceedings of a technical workshop on progress in yam research for development in West and Central Africa held in Accra, Ghana, 11–13 September 2007, (edited by B. Nkamleu, D. Annang, and N.M. Bacco), IFAD TAG 704, IITA, Nigeria.

Amanze, N.J., Agbo, N.J., Eke-Okoro, O.N. and Njoku, D.N. (2011). Selection of Yam Seeds from Open Pollination for Adoption in Yam (*Dioscorea rotundata* Poir) Production zones in Nigeria, *Journal of Plant Breeding and Crop Science* Vol. 3(4): pp. 68-73.

AMCOST (African Ministerial Council on Science and Technology) (2006). Technologies to reduce post-harvest food loss. African Ministerial Council on Science and Technology of the African Union (AU), Pretoria, South Africa, 2006. Available at; http://www.nepadst.org/platforms/foodloss.shtml. Accessed on 23rd March, 2013.

Amusa, N.A., Adegbite, A.A., Muhammed, S. and Baiyewu, R.A. (2003). Yam diseases and their management in Nigeria. *African Journal of Biotechnology Vol. 2(12)*: pp. 497- 502.

Barnett, H.L. and Hunter, B.B. (1972). *Illustrated Genera of Imperfect Fungi*. 3rd Edition. Burgess Publishing Company.

Booth, R.H. (1974). Post-harvest deterioration of tropical root crops. Losses and their control. *Trop. Sci. 16(2)*: pp. 49-63

Booth, R.H. and Proctor, F.J. (1972). Considerations relevant to the storage of ware potatoes in the tropics. *Pans. 18*: pp. 409-432.

Bradbury, J.H. and Holloway, W.D. (1988). Chemistry of tropical root crops: significance for nutrition and agriculture in the Pacific. ACIAR Monograph No. 6. Australian Centre for International Agricultural Research: Canberra

Chukwu, G.O. and Ikwelle, M.C (2000). Yam: Threats to its Sustainability in Nigeria, NRCRI News, *Umudike, 17(1)*: pp. 1-7.

Coursey, D.G. (1967). *Yams*. Longmans – London: p. 230

Coursey, D.G. (1981). Traditional post-harvest technology of tropical perishable staples contribution to storage losses. *Tropical Agriculture 55*: pp. 207-214.

Coursey, D.G. and Booth, R.H. (1972). The postharvest photopathology of perishable tropical produce. *Rev. Pl. Path. 51*: pp. 751-765.

Coursey, D.G., and Walker, H.M. (1960). A study of the origins of weight loss in stored yams. Rep, West Afr. Stored Prod. Res. Unit: pp. 61-64.

Coursey, D.G., Fellows, L.E. and Coulson, C.B. (1966). Respiration in yam tuber tissue. *Nature 210(5042):* pp. 1292-1293

Degras, L. (1993). *The yam: A Tropical Root Crop*. MacMillan Press, London.

FAO (Food and Agricultural Organisation) (1998). FAO Annual Report. Food and Agriculture Organisation Production Year Book. FAO Rome.

FAO (Food and Agricultural Organisation) (2000). F.A.O Statistics 1999. Food and Agricultural Organisation of the United Nations, Rome. Available at: http://faostat.fao.org/: Accessed on 23rd March, 2013.

FAO (Food and Agricultural Organisation) (2003). Agricultural Marketing and Food Security, In: Proceedings of the Mini Round Table Meeting on Agricultural Marketing and Food Security held at Bangkok, Thailand. 1- 2 Nov. 2001, Food and Agricultural Organisation

FAO (Food and Agricultural Organisation) (2006). FAO Annual Report. Food and Agriculture Organisation Production Year Book. Food and Agricultural Organisation) of the United Nations, Rome

FAO (Food and Agricultural Organisation) (2007). FAO Statistics 2006. Food and Agricultural Organisation of the United Nations, Rome. Available at http://faostat.fao.org/: Accessed on 23rd March, 2013.

FAO (Food and Agriculture Organization) (1990). Action Programme for the Prevention of Food Losses, Improving Post-Harvest Handling, Storage and Processing of Root and Tuber Crops, Rome.

Hahn, S.K, Osiru, D.S.O, Akoroda, M.O. and Otoo, J.A. (1987). Cassava and the African Food Crisis, *In*: TERRY, E.R. (ed.) (1987). Tropical Root Crops, Root Crops and the African Food Crisis, Nigeria.

Hahn, S.K. (1995). Yams, *Dioscorea* spp. (Dioscoreaceae). *In* '*Evolution of crop plants*'. (Ed.) by J. Smartt and N.W. Simmonds. Longman Scientific and Technical: London.

Ibrahim, M.H., Williams, J.O. and Abiodun, M.O. (1987). Assessment of parts of Neem tree for yam tuber storage. Rep. Nig. Stored Prod. Res. Inst., 4: 37–41.

Ihekeronye, A.I. and Ngoddy, P.O. (1985). *Integrated food science and technology for the tropics*. McMillan Publishers Ltd. London: pp. 266 – 282 and 366 – 368.

IITA (International Institute Tropical Agriculture) (1993). Crops Improvement Division/ Tuber root Improvement Program Archival Reports (1989-1993). Part III yam. Ibadan, Nigeria: pp. 20-85

IITA (International Institute Tropical Agriculture) (2006). Yam Research for Development. *IITA Publication, 1*: pp. 1-10.

Ikediobi, C.O. (1985). Biochemistry and physiology of yam storage. *In Advances in Yam Research, The Biochemistry and Technology of the yam Tuber.* (G.Osuji edt.). Biochemical Soc. Of Nigeria/Anambra State University of Technology. AI-United Industries & Shipping Inc. Taiwan Frontline Publishers, Enugu. 362 pp

Ikediobi, C.O. and Oti, E. (1983). Some biochemical changes associated with post-harvest storage of white yam (*Discorea rotundata*) tubers. *J. Sci. Food Agric. (34)*: pp. 1123 – 1129.

Ikotun, T. (1989). Diseases of yam tubers. International Journal of Tropical Plant Diseases (India): p. 21

Khan, M.R., Kihara, M. and Omoloso, A.D. (2001). Antimicrobial activity of *Cassia alata. Fitoterapia, 72*: pp. 561-564.

Knoth, J. (1993). Traditional storage of yams and cassava and its improvement. Deutsche Gesellschaft für Technische Zusammenarbit (GTZ) post- harvest project. Hamburg, Germany, pp. 9-43

Konesaroff, A., Black, V., Cable, V. and Sudhir K. (2001). Effects of wild yam extract on menopausal symptoms, lipids and sex hormones in healthy menopausal women. *Climacteric*, 4(2): pp. 144-50

Kuhn, P.J. and Hargreaves, J.A. (1987). Antifungal substances from herbaceous plants. In: FG Peggs and AG Ayes (eds). *Fungal infection of plants*. Symposium of the British Mycol. Soc. Cambridge Uni. Press: pp. 48-129.

Lawton, J.R. and Lawton, J.R.S. (1969). The Development of the tuber in seedlings of five species of (*Dioscrea alata*) during storage. *Experimental Agriculture 14*: pp. 167-172

Marthur, S.B. and Kongsdal, O. (2003). *Common Laboratory Seed Health Testing Methods for Detecting Fungi, 2nd Edition*. International Seed Testing Association. Switzerland

Morse, S., Acholo, M., McNamara, N. and Oliver, N. (2000). Control of storage insects as a means of limiting yam tuber fungal rots: *J. Stored Products Res. 36*: pp. 37-45

Mozie, O. (1984). Effect of air flow on weight losses and sprouting of white yam tubers stored in the conventional barn. Tropical Root and Tuber Crops News Letter 13: pp. 32-37.

National Academy of Sciences (1978). Post-harvest food losses in developing countries, U.S. National Academy of Sciences, Washington, D.C.

Noon, P.A. (1978). Storage and Market diseases of Yams. *Trop. Sci. 20*: pp. 17-81

Norman, M.J.T., Pearson, C.J. and Searle, P.G.E. (1995). *Tropical Food Crops in their environment 2nd Edition*. Cambridge Univ. press, U.K: pp. 305- 316.

Nwankiti, A.D.O. (1989). Traditional and Some Improved Storage Methods for Root and Tuber Crops in Nigeria. In Deutsche Stiftung F Internationale Entwicklung (Dse) (Edi.): Roots, Tubers and Legumes, Bonn: pp. 51 -67.

Nwankiti, O.A. and Arene, O.B. (1987). Diseases of yam in Nigeria. Pest Articles and News Summaries (PANS) 24: p. 468.

Nweke, T, Ugwu, B. and Asadu, C. (1991). Production costs in the yam-based cropping systems of southeastern Nigeria. RCMP Research Monograph No. 6. Ibadan, Nigeria: IITA

Ogundana, S.K., Naqvi, S.H.Z. and Ekundayo, J.A. (1970). Fungi associated with soft rot of yams *(Dioscorea spp.)* in storage in Nigeria. *Trans. Br. Mycol. Soc., 54*: pp. 445-451.

Ohene-Yankyera, K., Aidoo, R. and Ohenewah-Tawiah, E. (2011). Effects of Real Exchange Rate and Gross Domestic Product (GDP) on yam exports in Ghana, *Botswana Journal of Agriculture and Applied Sciences*, Vo. 7, (1): pp.57-63

Okigbo, R.N. and Ikediugwu, F.E.O. (2000). Studies on biological control of postharvest rot of yam with *Trichoderma viride*. *J. Phytopathol. 148*: pp. 351-355

Okigbo, R.N. and Ikediugwu, F.E.O. (2002). Evaluation of water losses in different regions of yam (*Dioscorea spp*.) tuber in storage. *Nig. J. Exp. Appl Bio. 3:* p. 320.

Okigbo, R.N. and Nmeka, I.A. (2005). Control of yam tuber rot with leaf extracts of *Xylopia aethiopica* and *Zingiber officinale*. Department Of Microbiology, Michael Okpara University of Agriculture, Umudike: p.806.

Okigbo, R.N. and Ogbonnaya, U.O. (2006). Antifungal effects of two tropical plant extracts (*Ocimum gratissimum* and *Aframomum melegueta*) on post-harvest yam rot. *African Journal of Biotechnology Vol. 5(9)*: pp. 727-731

Omonigho, S.E. (1988). Deterioration of pounded yam and its shelf life extension. MS thesis, University of Benin, Benin City, Nigeria

Onayemi, O. and Idowu, A. (1988). Physical and chemical changes in traditionally stored yam tubers (*Dioscorea rotundata*) poir and *Dioscorea cayenensis* Lam). Journal of Agricultural and Food Chemistry 36(3) 588-591

Onwueme, I.C. (1978). *The Tropical Tuber Crops: Yams, Cassava, Sweet potato, Cocoyams*. John Wiley and Sons, Ltd, Chichester, UK

Osagie, A.U. (1992). *The yam tuber in storage*. Postharvest Research Unit. Ambik Press. 11- 18pp

Osuji, G.O. and Umezurike, G.M. (1985). The biochemistry of yam tuber deterioration. *In Advances in Yam Research, The Biochemistry and Technology of the yam Tuber*. (G.Osuji ed.). Biochemical Soc. Of Nigeria/Anambra State University of Technology. AI-United Industries & Shipping Inc. Taiwan Frontline Publishers, Enugu: p 361.

Osunde, Z.D, Yisa, M.G. and El-Okene, A.M. (2003). Quality changes of yam under different storage structures. Proceedings of the Fourth International Conference and 25th Annual General Meeting of the Nigerian Institution of Agricultural Engineers held at Damaturu 25: pp. 206-212

Osunde, Z.D. (2008). Minimizing Postharvest Losses in Yam (*Dioscorea* spp.): Treatments and Techniques In: Robertson, G.L. and Lupien, J.R. (Eds), Using

Food Science and Technology to Improve Nutrition and Promote National Development, © International Union of Food Science and Technology

Osunde, Z.D. and Orhevba, B.A. (2009). Effects of storage conditions and storage period on nutritional and other qualities of stored yam (*Dioscorea spp)* tubers. *AJFAND 9(2):* pp. 678 – 690.

Passam, H.C., Read, S.J. and Rickard, J.E. (1978). The respiration of yam tubers and its contribution to storage losses. *Trop. Agric (55)*: pp. 207 – 214

Ravindran and Wanasundera (1992). Chemical changes in yam tubers, (*Dioscorea alata* and *esculenta*) during storage. *Tropical science 33*: pp. 57-62

Sahore, D.A., Nemlin, G.J. and Kamenan, A. (2007). Changes in nutritional properties of yam (*Dioscorea spp*), green plantain (*Musa spp*) and cassava (*Manihot esculenta*) during storage. *Food Science and Technology, (47)*: pp. 81 – 88

Serge, T. and Agbor-Egbe, T. (1996). Biochemical changes occurring during growth and storage of two yam species. *International Journal of Food Science and Nutrition 47*: pp. 93-102.7

Sp1ittstoesser, W.E. and Rhodes, A.M. (1973). Protein and amino acid values of some tropical root crops. *Illinois Research 15(4):* pp. 6-7.

Thamaga-Chitja, J.M, Hendriks, S.L., Ortmann, G.F. and Green, M. (2004). Impact of maize storage on rural household food security in Northern Kwazulu-Natal. *Tydskrifvir Gesinsekologie en Verbruikerswetenskappe, 32*: pp. 8-15. Available From;http://www.up.ac.za/academic/acadorgs/saafecs/vol32/chitja.pdf (Retrieved August 27, 2006).

Twumasi, J.K. (1986). Fungi associated with tar spot disease of water yam in Ghana. *Ghana Journal of Agricultural Science. 14(19)*: pp. 115-116

Ulbricht, C., Basch, E. and Sollars, D. (2002). Wild yam. *Journal of Herbal Pharmacotherapy, 3(4)*: pp. 77-91

Undie, A.S. and Akubue, P.I. (1986). Pharmacological evaluation of *Dioscorea dumetorum* tuber used in traditional anti-diabetic therapy. *J. Ethnopharmacol. 15*: pp. 133-14

Wanasundera, J.P.D. and Ravindran, G. (1994). Nutritional assessment of yam (*Dioscorea alata*) tubers. *Plant Foods for Human Nutrition 46(1):* pp. 33–39

Wilson, J.E. (1980). *Careful Storage of Yam.* Commonwealth Secretariat, London, England: pp. 2-8.

Wilson, J.E. (1982). Recent developments in the propagation of yam (*Dioscorea* spp): *In* '*Yams = ignames'*, ed. by J. Miege and S.N. Lyonga. Clarendon Press-Oxford: pp. 55–59

APPENDICE

Appendix 1: Analysis of Variance

1.1 Decay

Analysis of Variance Table for decay at wk_12

Source	DF	SS	MS	F	P
REPS	2	133.333	66.6667		
Cultivar	1	1.308E-31	1.308E-31	0.00	1.0000
Storage	2	133.333	66.6667	0.71	0.5129
Cultivar*Storage	2	400.000	200.000	2.14	0.1681
Error	10	933.333	93.3333		
Total	17	1600.00			

Grand Mean 6.6667 CV 144.91

Analysis of Variance Table for decay at wk_14

Source	DF	SS	MS	F	P
REPS	2	133.33	66.667		
Cultivar	1	88.89	88.889	0.35	0.5668
Storage	2	133.33	66.667	0.26	0.7738
Cultivar*Storage	2	311.11	155.556	0.61	0.5604
Error	10	2533.33	253.333		
Total	17	3200.00			

Grand Mean 13.333 CV 119.37

Analysis of Variance Table for decay at wk_16

Source	DF	SS	MS	F	P
REPS	2	311.11	155.556		
Cultivar	1	355.56	355.556	2.29	0.1615
Storage	2	311.11	155.556	1.00	0.4019
Cultivar*Storage	2	311.11	155.556	1.00	0.4019
Error	10	1555.56	155.556		
Total	17	2844.44			

Grand Mean 15.556 CV 80.18

Analysis of Variance Table for decay at wk_18

Source	DF	SS	MS	F	P
REPS	2	311.11	155.556		
Cultivar	1	355.56	355.556	2.76	0.1277
Storage	2	844.44	422.222	3.28	0.0805
Cultivar*Storage	2	311.11	155.556	1.21	0.3392
Error	10	1288.89	128.889		
Total	17	3111.11			

Grand Mean 17.778 CV 63.86

Analysis of Variance Table for decay wk_20

Source	DF	SS	MS	F	P
REPS	2	311.11	155.556		
Cultivar	1	355.56	355.556	2.76	0.1277
Storage	2	844.44	422.222	3.28	0.0805
Cultivar*Storage	2	311.11	155.556	1.21	0.3392
Error	10	1288.89	128.889		
Total	17	3111.11			

Grand Mean 17.778 CV 63.86

1.2 Pests/Rodent attack

Analysis of Variance Table for Rodent/Pest Attack

Source	DF	SS	MS	F	P
Reps	2	44.44	22.22		
Cultivar	1	3755.56	3755.56	76.82	0.0000
Storage	2	2177.78	1088.89	22.27	0.0002
Cultivar*Storage	2	2177.78	1088.89	22.27	0.0002
Error	10	488.89	48.89		
Total	17	8644.44			

Grand Mean 14.444 CV 48.41

1.3 Weight Loss

Analysis of Variance Table for Weight Loss

Source	DF	SS	MS	F	P
REPS	2	45.488	22.744		
STORAGE	2	32.060	16.030	0.82	0.4691
VARIETY	1	104.787	104.787	5.34	0.0434
STORAGE*VARIETY	2	0.277	0.139	0.01	0.9930
Error	10	196.171	19.617		
Total	17	378.783			

Grand Mean 23.534 CV 18.82

1.4 Sprout

Analysis of Variance Table for sprout

Source	**DF**	**SS**	**MS**	**F**	**P**
Reps	2	2533.33	1266.67		
Cultivar	1	2222.22	2222.22	6.17	0.0323
Storage	2	533.33	266.67	0.74	0.5012
Cultivar*Storage	2	711.11	355.56	0.99	0.4060
Error	10	3600.00	360.00		
Total	17	9600.00			

Grand Mean 66.667   CV 28.46

1.5 Proximate Analysis

1.5.1 Proximate analysis of white yam during storage

Analysis of Variance Table for Ash at storage

Source	**DF**	**SS**	**MS**	**F**	**P**
REPS	2	1.0201	0.51007		
VARIETY	1	0.5000	0.50000	0.98	0.3459
STORAGE	2	5.2500	2.62500	5.14	0.0292
VARIETY*STORAGE	2	3.2500	1.62500	3.18	0.0853
Error	10	5.1099	0.51099		
Total	17	15.1300			

Grand Mean 2.0000   CV 35.74

Analysis of Variance Table for Carbohydrate at storage

Source	**DF**	**SS**	**MS**	**F**	**P**
REPS	2	0.39908	0.19954		
VARIETY	1	0.10427	0.10427	0.46	0.5139
STORAGE	2	2.91604	1.45802	6.41	0.0162
VARIETY*STORAGE	2	2.65084	1.32542	5.82	0.0210
Error	10	2.27619	0.22762		
Total	17	8.34643			

Grand Mean 91.794   CV 0.52

Analysis of Variance Table for Fat at storage

Source	**DF**	**SS**	**MS**	**F**	**P**
REPS	2	0.00023	0.00012		
VARIETY	1	0.12500	0.12500	451.81	0.0000
STORAGE	2	0.25000	0.12500	451.81	0.0000
VARIETY*STORAGE	2	0.25000	0.12500	451.81	0.0000
Error	10	0.00277	0.00028		
Total	17	0.62800			

Grand Mean 1.0833   CV 1.54

Analysis of Variance Table for Fibre at storage

Source	DF	SS	MS	F	P
REPS	2	0.0022	0.00112		
VARIETY	1	0.1012	0.10125	467.31	0.0000
STORAGE	2	10.3075	5.15375	23786.5	0.0000
VARIETY*STORAGE	2	0.1899	0.09495	438.23	0.0000
Error	10	0.0022	0.00022		
Total	17	10.6031			

Grand Mean 2.2583 CV 0.65

Analysis of Variance Table for Moisture at storage

Source	DF	SS	MS	F	P
REPS	2	3.111E-04	1.556E-04		
VARIETY	1	499.069	499.069	1581558	0.0000
STORAGE	2	108.803	54.4017	172400	0.0000
VARIETY*STORAGE	2	5.59951	2.79976	8872.46	0.0000
Error	10	0.00316	3.156E-04		
Total	17	613.476			

Grand Mean 64.078 CV 0.03

Analysis of Variance Table for Protein at storage

Source	DF	SS	MS	F	P
REPS	2	0.00190	0.00095		
VARIETY	1	0.25205	0.25205	1008.20	0.0000
STORAGE	2	0.00160	0.00080	3.20	0.0843
VARIETY*STORAGE	2	3.99640	1.99820	7992.80	0.0000
Error	10	0.00250	0.00025		
Total	17	4.25445			

Grand Mean 5.1783 CV 0.31

1.5.2 Proximate analysis after storage

Analysis of Variance Table for Ash after storage

Source	DF	SS	MS	F	P
REPS	2	0.10484	0.05242		
VARIETY	1	0.04014	0.04014	0.69	0.4260
STORAGE	2	1.04074	0.52037	8.93	0.0060
VARIETY*STORAGE	2	1.17948	0.58974	10.12	0.0040
Error	10	0.58282	0.05828		
Total	17	2.94803			

Grand Mean 1.8661 CV 12.94

Analysis of Variance Table for Carbohydrate after storage

Source	DF	SS	MS	F	P
REPS	2	0.0005	0.0002		
VARIETY	1	0.1964	0.1964	758.45	0.0000
STORAGE	2	22.7557	11.3778	43948.7	0.0000
VARIETY*STORAGE	2	5.3942	2.6971	10418.0	0.0000
Error	10	0.0026	0.0003		
Total	17	28.3493			

Grand Mean 89.272 CV 0.02

Analysis of Variance Table for Fat after storage

Source	DF	SS	MS	F	P
REPS	2	0.00708	0.00354		
VARIETY	1	0.03209	0.03209	7.98	0.0180
STORAGE	2	0.06854	0.03427	8.53	0.0069
VARIETY*STORAGE	2	0.06168	0.03084	7.67	0.0096
Error	10	0.04019	0.00402		
Total	17	0.20958			

Grand Mean 1.0211 CV 6.21

Analysis of Variance Table for Fibre after storage

Source	DF	SS	MS	F	P
REPS	2	0.08874	0.04437		
VARIETY	1	0.50334	0.50334	8.53	0.0153
STORAGE	2	6.79588	3.39794	57.59	0.0000
VARIETY*STORAGE	2	1.18014	0.59007	10.00	0.0041
Error	10	0.59006	0.05901		
Total	17	9.15816			

Grand Mean 2.2372 CV 10.86

Analysis of Variance Table for Moisture after storage

Source	DF	SS	MS	F	P
REPS	2	2.333E-04	1.166E-04		
VARIETY	1	506.150	506.150	2410239	0.0000
STORAGE	2	183.811	91.9055	437645	0.0000
VARIETY*STORAGE	2	0.63734	0.31867	1517.49	0.0000
Error	10	0.00210	2.100E-04		
Total	17	690.601			

Grand Mean 61.938 CV 0.02

Analysis of Variance Table for Protein after storage

Source	DF	SS	MS	F	P
REPS	2	0.00043	0.00022		
VARIETY	1	0.21780	0.21780	3843.53	0.0000
STORAGE	2	0.00430	0.00215	37.94	0.0000
Cultiva*STORAGE	2	4.12770	2.06385	36420.9	0.0000
Error	10	0.00057	0.00006		
Total	17	4.35080			

Grand Mean 5.1233 CV 0.15

1.6 Dry Matter Content

Analysis of Variance Table for Dry Matter content

Source	DF	SS	MS	F	P
Reps	2	44.3333	22.1667		
Variety	1	24.5000	24.5000	43.24	0.0001
Storage	2	12.0000	6.00000	10.59	0.0034
Variety*Storage	2	1.233E-28	6.163E-29	0.00	1.0000
Error	10	5.66667	0.56667		
Total	17	86.5000			

Grand Mean 40.500   CV 1.86

1.7 Transformed Data

Analysis of Variance Table for sprout

Source	DF	SS	MS	F	P
Reps	2	0.48201	0.24100		
Cultivar	1	0.42308	0.42308	7.14	0.0234
Storage	2	0.12390	0.06195	1.05	0.3870
Cultivar*Storage	2	0.16507	0.08253	1.39	0.2927
Error	10	0.59255	0.05926		
Total	17	1.78661			

Grand Mean 1.9467   CV 12.50

Analysis of Variance Table for pest attack/damage

Source	DF	SS	MS	F	P
Reps	2	0.01197	0.00598		
Cultivar	1	1.66056	1.66056	129.07	0.0000
Storage	2	0.90325	0.45163	35.10	0.0000
Cultivar*Storage	2	0.90325	0.45163	35.10	0.0000
Error	10	0.12866	0.01287		
Total	17	3.60769			

Grand Mean 1.0108   CV 11.22

Analysis of Variance Table for weight loss

Source	DF	SS	MS	F	P
Reps	2	0.46401	0.23200		
Cultivar	1	1.06284	1.06284	5.61	0.0393
Storage	2	0.35323	0.17661	0.93	0.4252
Cultivar*Storage	2	0.00567	0.00284	0.01	0.9852
Error	10	1.89349	0.18935		
Total	17	3.77925			

Grand Mean 4.8810   CV 8.92

Appendix 2: Means and Corresponding Least significant difference (Lsd) values

2.1: Decay Means

LSD All-Pairwise Comparisons Test of decay for Cultivar

Cultivar	Mean	Homogeneous Groups
PONA	22.222	A
TELA	13.333	A

Alpha 0.05 Standard Error for Comparison 5.3518
Critical T Value 2.228 Critical Value for Comparison 11.925

LSD All-Pairwise Comparisons Test of decay for Storage

Storage	Mean	Homogeneous Groups
Heaps	26.667	A
Trad barn	16.667	AB
Open Side	10.000	B

Alpha 0.05 Standard Error for Comparison 6.5546
Critical T Value 2.228 Critical Value for Comparison 14.605

LSD All-Pairwise Comparisons Test of decay for Cultivar*Storage

Cultivar	Storage	Mean	Homogeneous Groups
PONA	Heaps	26.667	A
PONA	Trad barn	26.667	A
TELA	Heaps	26.667	A
PONA	Open Side	13.333	A
TELA	Open Side	6.667	A
TELA	Trad barn	6.667	A

Alpha 0.05 Standard Error for Comparison 9.2696
Critical T Value 2.228 Critical Value for Comparison 20.654

2.2: Pests/Rodent Attack Means

LSD All-Pairwise Comparisons Test of Pests/rodent for Cultivar

Cultivar	Mean	Homogeneous Groups
PONA	28.889	A
TELA	0.0000	B

Alpha 0.05 Standard Error for Comparison 3.2961
Critical T Value 2.228 Critical Value for Comparison **7.3441**

LSD All-Pairwise Comparisons Test of Pests/rodent for Storage

Storage	Mean	Homogeneous Groups
Heaps	26.667	A
Trad barn	16.667	B
Open Side	0.0000	C

Alpha 0.05 Standard Error for Comparison 4.0369
Critical T Value 2.228 Critical Value for Comparison **8.9947**

LSD All-Pairwise Comparisons Test of Pests/rodent for Cultivar*Storage

Cultivar	Storage	Mean	Homogeneous Groups
PONA	Heaps	53.333	A
PONA	Trad barn	33.333	B
PONA	Open Side	0.0000	C
TELA	Heaps	0.0000	C
TELA	Open Side	0.0000	C
TELA	Trad barn	0.0000	C

Alpha 0.05 Standard Error for Comparison 5.7090
Critical T Value 2.228 Critical Value for Comparison **12.720**

2.3: Weight Loss Means

LSD All-Pairwise Comparisons Test of Weight Loss for Storage

Storage	Mean	Homogeneous Groups
Open Side	25.402	A
Heaps	22.835	A
Trad barn	22.365	A

Alpha 0.05 Standard Error for Comparison 2.5572
Critical T Value 2.228 Critical Value for Comparison 5.6977

LSD All-Pairwise Comparisons Test of Weight Loss for Cultivar

Cultivar	Mean	Homogeneous Groups
TELA	25.947	A
PONA	21.121	B

Alpha 0.05 Standard Error for Comparison 2.0879
Critical T Value 2.228 Critical Value for Comparison 4.6521

LSD All-Pairwise Comparisons Test of Weight Loss for Storage*Cultivar

Storage	Cultivar	Mean	Homogeneous Groups
Open Side	TELA	27.960	A
Heaps	TELA	25.090	A
Trad barn	TELA	24.790	A
Open Side	PONA	22.843	A
Heaps	PONA	20.580	A
Trad barn	PONA	19.940	A

Alpha 0.05 Standard Error for Comparison 3.6164
Critical T Value 2.228 Critical Value for Comparison 8.0578

2.4: Sprout

LSD All-Pairwise Comparisons Test of sprout for Cultivar

Cultivar	Mean	Homogeneous Groups
TELA	77.778	A
PONA	55.556	B

Alpha 0.05 Standard Error for Comparison 8.9443
Critical T Value 2.228 Critical Value for Comparison 19.929

LSD All-Pairwise Comparisons Test of sprout for Storage

Storage	Mean	Homogeneous Groups
Trad barn	73.333	A
Heaps	66.667	A
Open Side	60.000	A

Alpha 0.05 Standard Error for Comparison 10.954
Critical T Value 2.228 Critical Value for Comparison 24.408

LSD All-Pairwise Comparisons Test of wk_20 for Cultivar*Storage

Cultivar	Storage	Mean	Homogeneous Groups
TELA	Trad barn	93.333	A
TELA	Heaps	73.333	AB
TELA	Open Side	66.667	AB
PONA	Heaps	60.000	AB
PONA	Open Side	53.333	B
PONA	Trad barn	53.333	B

Alpha 0.05 Standard Error for Comparison 15.492
Critical T Value 2.228 Critical Value for Comparison 34.518

2.5: Nutritional Composition Means

2.5.1: Proximate analysis during storage

LSD All-Pairwise Comparisons Test of Ash for Storage at storage

Storage	Mean	Homogeneous Groups
Heaps	2.7500	A
Open Side	1.7500	A
Trad barn	1.5000	A

Alpha 0.01 Standard Error for Comparison 0.4127
Critical T Value 3.169 Critical Value for Comparison 1.3080

LSD All-Pairwise Comparisons Test of Ash for Cultivar at storage

Cultivar	Mean	Homogeneous Groups
PONA	2.1667	A
TELA	1.8333	A

Alpha 0.01 Standard Error for Comparison 0.3370
Critical T Value 3.169 Critical Value for Comparison 1.0680

LSD All-Pairwise Comparisons Test of Ash for Storage*Cultivar at storage

Storage	Cultivar	Mean	Homogeneous Groups
Heaps	PONA	3.5000	A
Heaps	TELA	2.0000	AB
Open Side	TELA	2.0000	AB
Open Side	PONA	1.5000	B
Trad barn	PONA	1.5000	B
Trad barn	TELA	1.5000	B

Alpha 0.01 Standard Error for Comparison 0.5837
Critical T Value 3.169 Critical Value for Comparison 1.8498

LSD All-Pairwise Comparisons Test of Carbohydrate for Storage at storage

Storage	Mean	Homogeneous Groups
Trad barn	92.315	A
Open Side	91.732	AB
Heaps	91.335	B

Alpha 0.01 Standard Error for Comparison 0.2755
Critical T Value 3.169 Critical Value for Comparison 0.8730

LSD All-Pairwise Comparisons Test of Carbohydrate for Cultivar at storage

Cultivar	Mean	Homogeneous Groups
PONA	91.870	A
TELA	91.718	A

Alpha 0.01 Standard Error for Comparison 0.2249
Critical T Value 3.169 Critical Value for Comparison 0.7128

LSD All-Pairwise Comparisons Test of Carbohydrate for Storage*Cultivar at storage

Storage	Cultivar	Mean	Homogeneous Groups
Trad barn	PONA	92.860	A
Open Side	PONA	91.810	AB
Trad barn	TELA	91.770	AB
Heaps	TELA	91.730	AB
Open Side	TELA	91.653	AB
Heaps	PONA	90.940	B

Alpha 0.01 Standard Error for Comparison 0.3895
Critical T Value 3.169 Critical Value for Comparison 1.2346

LSD All-Pairwise Comparisons Test of Fat for Storage at storage

Storage	Mean	Homogeneous Groups
Heaps	1.2500	A
Open Side	1.0000	B
Trad barn	1.0000	B

Alpha 0.01 Standard Error for Comparison 9.603E-03
Critical T Value 3.169 Critical Value for Comparison 0.0304

LSD All-Pairwise Comparisons Test of Fat for Cultivar at storage

Cultivar	Mean	Homogeneous Groups
TELA	1.1667	A
PONA	1.0000	B

Alpha 0.01 Standard Error for Comparison 7.841E-03
Critical T Value 3.169 Critical Value for Comparison 0.0249

All-Pairwise Comparisons Test of Fat for Storage*Cultivar at storage

Storage	Cultivar	Mean	Homogeneous Groups
Heaps	TELA	1.5000	A
Heaps	PONA	1.0000	B
Open Side	PONA	1.0000	B
Open Side	TELA	1.0000	B
Trad barn	PONA	1.0000	B
Trad barn	TELA	1.0000	B

Alpha 0.01 Standard Error for Comparison 0.0136
Critical T Value 3.169 Critical Value for Comparison 0.0430

LSD All-Pairwise Comparisons Test of Fibre for Storage at storage

Storage	Mean	Homogeneous Groups
Open Side	3.3000	A
Heaps	1.9500	B
Trad barn	1.5250	C

Alpha 0.01 Standard Error for Comparison 8.498E-03
Critical T Value 3.169 Critical Value for Comparison 0.0269

LSD All-Pairwise Comparisons Test of Fibre for Cultivar at storage

Cultivar	Mean	Homogeneous Groups
TELA	2.3333	A
PONA	2.1833	B

Alpha 0.01 Standard Error for Comparison 6.939E-03
Critical T Value 3.169 Critical Value for Comparison 0.0220

LSD All-Pairwise Comparisons Test of Fibre for Storage*Cultivar at storage

Storage	Cultivar	Mean	Homogeneous Groups
Open Side	TELA	3.5200	A
Open Side	PONA	3.0800	B
Heaps	TELA	1.9600	C
Heaps	PONA	1.9400	C
Trad barn	PONA	1.5300	D
Trad barn	TELA	1.5200	D

Alpha 0.01 Standard Error for Comparison 0.0120
Critical T Value 3.169 Critical Value for Comparison 0.0381

LSD All-Pairwise Comparisons Test of Moisture for Storage

Storage	Mean	Homogeneous Groups
Open Side	67.413	A
Heaps	63.260	B
Trad barn	61.560	C

Alpha 0.01 Standard Error for Comparison 0.0103
Critical T Value 3.169 Critical Value for Comparison 0.0325

LSD All-Pairwise Comparisons Test of Moisture for Cultivar at storage

Cultivar	Mean	Homogeneous Groups
PONA	69.343	A
TELA	58.812	B

Alpha 0.01 Standard Error for Comparison 8.374E-03
Critical T Value 3.169 Critical Value for Comparison 0.0265

LSD All-Pairwise Comparisons Test of Moisture for Storage*Cultivar at storage

Storage	Cultivar	Mean	Homogeneous Groups
Open Side	PONA	73.460	A
Heaps	PONA	68.230	B
Trad barn	PONA	66.340	C
Open Side	TELA	61.367	D
Heaps	TELA	58.290	E
Trad barn	TELA	56.780	F

Alpha 0.01 Standard Error for Comparison 0.0145
Critical T Value 3.169 Critical Value for Comparison 0.0460

LSD All-Pairwise Comparisons Test of Protein for Storage at storage

Storage	Mean	Homogeneous Groups
Open Side	5.1850	A
Trad barn	5.1850	A
Heaps	5.1650	A

Alpha 0.01 Standard Error for Comparison 9.129E-03
Critical T Value 3.169 Critical Value for Comparison 0.0289

LSD All-Pairwise Comparisons Test of Protein for Cultivar at storage

Cultivar	Mean	Homogeneous Groups
PONA	5.2967	A
TELA	5.0600	B

Alpha 0.01 Standard Error for Comparison 7.454E-03
Critical T Value 3.169 Critical Value for Comparison 0.0236

LSD All-Pairwise Comparisons Test of Protein for Storage*Cultivar

Storage	cultivar	Mean	Homogeneous Groups
Trad barn	TELA	5.7300	A
Open Side	PONA	5.6900	A
Heaps	PONA	5.5600	B
Heaps	TELA	4.7700	C
Open Side	TELA	4.6800	D
Trad barn	PONA	4.6400	D

Alpha 0.01 Standard Error for Comparison 0.0129
Critical T Value 3.169 Critical Value for Comparison 0.0409
Error term used: REPS*STORAGE*VARIETY, 10 DF

2.5.2: Proximate analysis after storage

LSD All-Pairwise Comparisons Test of Ash for Cultivar

Cultivar	Mean	Homogeneous Groups
PONA	1.9133	A
TELA	1.8189	A

Alpha 0.01 Standard Error for Comparison 0.1138
Critical T Value 3.169 Critical Value for Comparison 0.3607

LSD All-Pairwise Comparisons Test of Ash for Storage

Storage	Mean	Homogeneous Groups
Heaps	2.1683	A
Open Side	1.8500	AB
Trad barn	1.5800	B

Alpha 0.01 Standard Error for Comparison 0.1394
Critical T Value 3.169 Critical Value for Comparison 0.4417
Error term used: REPS*CULTIVAR*STORAGE, 10 DF

LSD All-Pairwise Comparisons Test of Ash for Cultivar*Storage

Cultivar	Storage	Mean	Homogeneous Groups
PONA	Heaps	2.5500	A
TELA	Open Side	2.0900	AB
TELA	Heaps	1.7867	B
PONA	Open Side	1.6100	B
PONA	Trad barn	1.5800	B
TELA	Trad barn	1.5800	B

Alpha 0.01 Standard Error for Comparison 0.1971
Critical T Value 3.169 Critical Value for Comparison 0.6247

LSD All-Pairwise Comparisons Test of Carbohydrate for Cultivar

Cultivar	Mean	Homogeneous Groups
TELA	89.377	A
PONA	89.168	B

Alpha 0.01 Standard Error for Comparison 7.585E-03
Critical T Value 3.169 Critical Value for Comparison 0.0240

LSD All-Pairwise Comparisons Test of Carbohydrate for Storage

Storage	Mean	Homogeneous Groups
Open Side	90.682	A
Trad barn	89.205	B
Heaps	87.930	C

Alpha 0.01 Standard Error for Comparison 9.290E-03
Critical T Value 3.169 Critical Value for Comparison 0.0294

LSD All-Pairwise Comparisons Test of Carbohydrate for Cultivar*Storage

Cultivar	**Storage**	**Mean**	**Homogeneous Groups**
TELA	Open Side	91.540	A
PONA	Open Side	89.823	B
PONA	Trad barn	89.630	C
TELA	Trad barn	88.780	D
PONA	Heaps	88.050	E
TELA	Heaps	87.810	F

Alpha 0.01 Standard Error for Comparison 0.0131
Critical T Value 3.169 Critical Value for Comparison 0.0416

LSD All-Pairwise Comparisons Test of Fat for Cultivar

Cultivar	**Mean**	**Homogeneous Groups**
TELA	1.0633	A
PONA	0.9789	A

Alpha 0.01 Standard Error for Comparison 0.0299
Critical T Value 3.169 Critical Value for Comparison 0.0947

LSD All-Pairwise Comparisons Test of Fat for Storage

Storage	**Mean**	**Homogeneous Groups**
Heaps	1.1083	A
Open Side	0.9800	B
Trad barn	0.9750	B

Alpha 0.01 Standard Error for Comparison 0.0366
Critical T Value 3.169 Critical Value for Comparison 0.1160

LSD All-Pairwise Comparisons Test of Fat for Cultivar*Storage

Cultivar	**Storage**	**Mean**	**Homogeneous Groups**
TELA	Heaps	1.2333	A
PONA	Heaps	0.9833	B
PONA	Open Side	0.9800	B
TELA	Open Side	0.9800	B
TELA	Trad barn	0.9767	B
PONA	Trad barn	0.9733	B

Alpha 0.01 Standard Error for Comparison 0.0518
Critical T Value 3.169 Critical Value for Comparison 0.1640

LSD All-Pairwise Comparisons Test of Fibre for Cultivar

Cultivar	**Mean**	**Homogeneous Groups**
TELA	2.4044	A
PONA	2.0700	A

Alpha 0.01 Standard Error for Comparison 0.1145
Critical T Value 3.169 Critical Value for Comparison 0.3629

LSD All-Pairwise Comparisons Test of Fibre for Storage

Storage	Mean	Homogeneous Groups
Open Side	3.0717	A
Heaps	2.0300	B
Trad barn	1.6100	B

Alpha 0.01 Standard Error for Comparison 0.1402
Critical T Value 3.169 Critical Value for Comparison 0.4445

LSD All-Pairwise Comparisons Test of Fibre for Cultivar*Storage

Cultivar	Storage	Mean	Homogeneous Groups
TELA	Open Side	3.6000	A
PONA	Open Side	2.5433	B
PONA	Heaps	2.0667	BC
TELA	Heaps	1.9933	BC
TELA	Trad barn	1.6200	C
PONA	Trad barn	1.6000	C

Alpha 0.01 Standard Error for Comparison 0.1983
Critical T Value 3.169 Critical Value for Comparison 0.6286

LSD All-Pairwise Comparisons Test of Moisture for Cultivar

Cultivar	Mean	Homogeneous Groups
PONA	67.241	A
TELA	56.636	B

Alpha 0.01 Standard Error for Comparison 6.831E-03
Critical T Value 3.169 Critical Value for Comparison 0.0217

LSD All-Pairwise Comparisons Test of Moisture for Storage

Storage	Mean	Homogeneous Groups
Open Side	65.937	A
Heaps	61.763	B
Trad barn	58.115	C

Alpha 0.01 Standard Error for Comparison 8.367E-03
Critical T Value 3.169 Critical Value for Comparison 0.0265

LSD All-Pairwise Comparisons Test of Moisture for Cultivar*Storage

Cultivar	Storage	Mean	Homogeneous Groups
PONA	Open Side	71.373	A
PONA	Heaps	66.800	B
PONA	Trad barn	63.550	C
TELA	Open Side	60.500	D
TELA	Heaps	56.727	E
TELA	Trad barn	52.680	F

Alpha 0.01 Standard Error for Comparison 0.0118
Critical T Value 3.169 Critical Value for Comparison 0.0375

LSD All-Pairwise Comparisons Test of Protein for Cultivar

Cultivar Mean Homogeneous Groups
PONA 5.2333 A
TELA 5.0133 B

Alpha 0.01 Standard Error for Comparison 3.549E-03
Critical T Value 3.169 Critical Value for Comparison 0.0112

LSD All-Pairwise Comparisons Test of Protein for Storage

Storage Mean Homogeneous Groups
Open Side 5.1450 A
Trad barn 5.1150 B
Heaps 5.1100 B

Alpha 0.01 Standard Error for Comparison 4.346E-03
Critical T Value 3.169 Critical Value for Comparison 0.0138

LSD All-Pairwise Comparisons Test of Protein for Cultivar*Storage

Cultivar Storage Mean Homogeneous Groups
TELA Trad barn 5.6800 A
PONA Open Side 5.6400 B
PONA Heaps 5.5100 C
TELA Heaps 4.7100 D
TELA Open Side 4.6500 E
PONA Trad barn 4.5500 F

Alpha 0.01 Standard Error for Comparison 6.146E-03
Critical T Value 3.169 Critical Value for Comparison 0.0195

2.6: Dry Matter Content Means

LSD All-Pairwise Comparisons Test of DM for Cultivar

Cultiar Mean Homogeneous Groups
Tela 41.667 A
Pona 39.333 B

Alpha 0.01 Standard Error for Comparison 0.3549
Critical T Value 3.169 Critical Value for Comparison 1.1246

LSD All-Pairwise Comparisons Test of DM for Storage

Storage Mean Homogeneous Groups
Trad barn 41.500 A
Open Side 40.500 AB
Heaps 39.500 B

Alpha 0.01 Standard Error for Comparison 0.4346
Critical T Value 3.169 Critical Value for Comparison 1.3774
Error term used: Reps*Variety*Storage, 10 DF

LSD All-Pairwise Comparisons Test of DM for Cultivar*Storage

Cultivar	Storage	Mean	Homogeneous Groups
Tela	Trad barn	42.667	A
Tela	Open Sided	41.667	AB
Tela	Heaps	40.667	BC
Pona	Trad barn	40.333	BC
Pona	Open Side	39.333	CD
Pona	Heaps	38.333	D

Alpha 0.01 Standard Error for Comparison 0.6146
Critical T Value 3.169 Critical Value for Comparison 1.9479

2.7 Transformed Data

LSD All-Pairwise Comparisons Test of sprout for Cultivar

Cultivar	Mean	Homogeneous Groups
Tela	2.1000	A
Pona	1.7934	B

Alpha 0.05 Standard Error for Comparison 0.1148
Critical T Value 2.228 Critical Value for Comparison 0.2557
Error term used: Reps*Cultivar*Storage, 10 DF
All 2 means are significantly different from one another.

LSD All-Pairwise Comparisons Test of sprout for Storage

Storage	Mean	Homogeneous Groups
Trad barn	2.0499	A
Heaps	1.9434	A
Open Side	1.8468	A

Alpha 0.05 Standard Error for Comparison 0.1405
Critical T Value 2.228 Critical Value for Comparison 0.3131
Error term used: Reps*Cultivar*Storage, 10 DF
There are no significant pairwise differences among the means.

LSD All-Pairwise Comparisons Test of sprout for Cultivar*Storage

Cultivar	Storage	Mean	Homogeneous Groups
Tela	Trad barn	2.3387	A
Tela	Heaps	2.0290	AB
Tela	Open Side	1.9324	AB
Pona	Heaps	1.8578	B
Pona	Open Side	1.7612	B
Pona	Trad barn	1.7612	B

Alpha 0.05 Standard Error for Comparison 0.1988
Critical T Value 2.228 Critical Value for Comparison 0.4429
Error term used: Reps*Cultivar*Storage, 10 DF
There are 2 groups (A and B) in which the means are not significantly different from one another.

LSD All-Pairwise Comparisons Test of pest attack/damage for Cultivar

Cultivar	Mean	Homogeneous Groups
Pona	1.3146	A
Tela	0.7071	B

Alpha 0.05 Standard Error for Comparison 0.0535
Critical T Value 2.228 Critical Value for Comparison 0.1191
Error term used: Reps*Cultivar*Storage, 10 DF
All 2 means are significantly different from one another.

LSD All-Pairwise Comparisons Test of pest pest attack/damage for Storage

Storage	Mean	Homogeneous Groups
Heaps	1.2407	A
Trad barn	1.0847	B
Open Side	0.7071	C

Alpha 0.05 Standard Error for Comparison 0.0655
Critical T Value 2.228 Critical Value for Comparison 0.1459
Error term used: Reps*Cultivar*Storage, 10 DF
All 3 means are significantly different from one another.

LSD All-Pairwise Comparisons Test of pest attack/damage for Cultivar*Storage

Cultivar	Storage	Mean	Homogeneous Groups
Pona	Heaps	1.7743	A
Pona	Trad barn	1.4623	B
Pona	Open Side	0.7071	C
Tela	Heaps	0.7071	C
Tela	Open Side	0.7071	C
Tela	Trad barn	0.7071	C

Alpha 0.05 Standard Error for Comparison 0.0926
Critical T Value 2.228 Critical Value for Comparison 0.2064
Error term used: Reps*Cultivar*Storage, 10 DF
There are 3 groups (A, B, etc.) in which the means are not significantly different from one another.

LSD All-Pairwise Comparisons Test of weight Loss for Cultivar

Cultivar	Mean	Homogeneous Groups
Tela	5.1240	A
Pona	4.6380	B

Alpha 0.05 Standard Error for Comparison 0.2051
Critical T Value 2.228 Critical Value for Comparison 0.4571
Error term used: Reps*Cultivar*Storage, 10 DF
All 2 means are significantly different from one another.

LSD All-Pairwise Comparisons Test of weight Loss for Storage

Storage	Mean	Homogeneous Groups
Open Side	5.0787	A
Heaps	4.7925	A
Trad barn	4.7717	A

Alpha 0.05 Standard Error for Comparison 0.2512
Critical T Value 2.228 Critical Value for Comparison 0.5598
Error term used: Reps*Cultivar*Storage, 10 DF
There are no significant pairwise differences among the means.

LSD All-Pairwise Comparisons Test of weight Loss for Cultivar*Storage

Cultivar	Storage	Mean	Homogeneous Groups
Tela	Open Side	5.3346	A
Tela	Trad barn	5.0268	AB
Tela	Heaps	5.0104	AB
Pona	Open Side	4.8228	AB
Pona	Heaps	4.5746	AB
Pona	Trad barn	4.5165	B

Alpha 0.05 Standard Error for Comparison 0.3553
Critical T Value 2.228 Critical Value for Comparison 0.7916
Error term used: Reps*Cultivar*Storage, 10 DF
There are 2 groups (A and B) in which the means are not significantly different from one another.

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY
DEPARTMENT OF HORTICULTURE

This questionnaire is designed to evaluate post harvest losses in yam during storage in the major yam producing areas in the Brong Ahafo region of Ghana. Please be as objective as possible.

BIODATA OF FARMERS

1. Sex of respondent a. male [ ] b. female [ ]

2. Age of respondent a. 20-29 yrs [ ] b. 30-39 yrs [ ] c. 40-49 yrs [ ] d. 50-59 yrs [ ] e. 60 years and above [ ] If below 18 state age……………………

3. Marital status a. single [ ] b. married [ ] c. divorced [ ] d. widowed [ ]

4. Educational background a. No formal education [ ] b. primary [ ] c. MSLC/JHS [ ] d. SHS/Voc/Tech [ ] d. tertiary [ ]

5. Religious background a. Christian [ ] b. Muslim [ ] c. traditionalist [ ] d. others [ ] specify……………………………………………………………………………

6. What is your main occupation? ……………………………………………………………

7. Do you engage in any other activity apart from your main occupation? a. yes [ ] b. no [ ]

8. If yes, what other activity? ……………………………………………………………

9. Do you produce yam? a. yes [ ] b. no [ ]

PRODUCTION DATA

10. Which type of farm do you have? a. subsistence farming [ ] b. commercial farming [ ]

11. How many mounds do you plant in a season? a. Less than 100 b. 100-500 c. 501-1000 d. Above 1000

12. What type of farming system do you practice? a. mono-cropping [ ] b. mixed cropping c. intercropping [ ] d. others [ ], specify……………………………………

13. What other crop(s) do you cultivate in addition to the yam? ……………………………

14. What species of yam do you cultivate? a. White yam [ ] b. Water yam [ ] others (specify) ……………………………………………………………………………

15.Which white yam variety do you cultivate? a.pona [ ] b.tela [ ] c. doben [ ] d. Serwaa [ ] e. dente [ ] (f) others specify……………………………………………

16. What planting material do you use in farm establishment? a. seed [ ] b. setts [ ] c. Minisetts

17. What is the source of your planting materials? a. own farm [ ] b. friends [ ] c. research stations [ ] d. market [ ] e. others [ ], specify ………………………

18. Do you keep records on all your farming activities? a. yes [ ] b. no [ ] Why?
…………………………………………………………………………………………

CULTURAL PRACTICES

19. Which of the following cultural activities do you carry out on your farm?

a. Irrigation	[ ]	b. Fertilizer application	[ ]
c. Weed control	[ ]	d. Mulching	[ ]
e. Pruning	[ ]	f. Staking	[ ]
g. Disease and pests control	[ ]	h. Milking	

20. What type of fertilizer do you use? a. NPK 15-15-15 [ ] b. Animal manure [ ] c. others [ ], specify ……………………………………………………………

21. Why do you apply fertilizer? ……………………………………………………………

22. How many times do you weed your farm in a year? a. once [ ] b. twice [ ] c. thrice [ ] d. four times [ ] e. others [ ], specify ……………………………

23. Why? ……………………………………………

24. What material do you use in mulching? ……………………………………………

25. Why do you mulch?
…………………………………………………………………………

26. What do you prune? a. Excessive vines [ ] b. diseased vines [ ] c. dead vines [ ]

27. Why do you prune? ……………………………………………………………

28. What type of pests have you observed on your farm? ……………………………

29. What type of disease have you observed on your farm? ....

30. How often do you control pests and diseases on your crops?
a. routine spraying with chemicals [ ] b. whenever they occur [✓] c. Nill

HARVESTING /TREATMENTS/STORAGE

31. How many times do you harvest your yam in a season? a. once [ ] b. Twice [ ]

32. How do you determine the stage of maturity of the tuber? a. visual observation [✓] b. Calendar date [ ]

33. What tool do you use in harvesting the yam? ....

34. How many yams do you harvest per season? a. less than 100 [ ] b. 100-500 [ ] c. 601-1000 [✓] d. more than 1000

35. What do you do after harvest? a. sell [ ] b. store [ ] c. Both [ ]

36. Why do you sell your yam after harvest? ....

37. Why do you store your yam after harvest? ....

38. Do you apply any treatment to the yam before storing? a. yes [ ] b. no [✓]

39. If yes, what treatment(s) do you apply? ....

40. Why do you apply the treatment(s)? ....

41. How do you store the yams? a. Barn [ ] b. Burial in the soil [ ] c. Heaping on the floor covered with straw [ ]

42. Why do you use the method indicated above? ....

43. What other ways do you use for storing the yam?
....

44. Why do you use this method? ....
45 Under very good storage conditions how long are the tubers expected to maintain the best of eating and marketing qualities? ....

46. How long have you being able to maintain the best of eating and marketing qualities using the method(s)
Indicated above? ……………………………………………………………………………

47. How much of your stored yam are lost? A. 1-10% [ ] b. 11-20% [ ] c. 21-30% [ ] d. 31-40% [ ] e. 41-50% [ ] f. Above 50%

48. What is/are the causes of the losses? a Injuries [ ] b. Pest [ ] c. Decay [ ] e. Sprouting [ ] f. Weight Loss [ ]

49. How do you control these losses?

a. Injuries
………………………………………………………………………………………………………

b. Pest
………………………………………………………………………………………………………
..

c. Decay
………………………………………………………………………………………………………
..

d. Sprouting
………………………………………………………………………………………………………

e. Weight Loss
………………………………………………………………………………………………………
…………

50. What other constraints affect your yam production business? ………………………