# KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

COLLEGE OF ENGINEERING

## DEPARTMENT OF AGRICULTURAL ENGINEERING


BY

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# ASSESSING THE POST – HARVEST PERFORMANCE OF TWO YAM

# VARIETIES (*DIOSCOREA SPECIES*) UNDER TWO IMPROVED

# STRUCTURES IN THE EJURA – SEKYEDUMASE DISTRICT OF ASHANTI

# REGION

BY

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BSc. (Hons.) Agriculture

This Thesis is presented to the Department of Agricultural Engineering, Kwame Nkrumah University of Science And Technology, Kumasi in Partial Fulfillment of the Requirements of the Degree of

**MASTER OF PHILOSOPHY (MPHIL) FOOD AND POST- HARVEST ENGINEERING**

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KNUST

**DECLARATION**

I hereby declare that this study was wholly carried out by me, EDWARD OWUSU TENADU, of College of Engineering, Department of Agricultural Engineering, Kwame Nkrumah University of Science and Technology, Kumasi at Kasei via Ejura in the Ashanti Region of Ghana reported herein under the supervision of Prof. K. A Dzisi. I further testify that this thesis has never been presented on any occasion in its entirety or part at any University for the award of a degree and that any literature cited herein has been duly acknowledged.

Edward Owusu Tenadu
(Student) ………................................. …………………….
Signature Date

Certified by:
Professor Komla A. Dzisi .................................. …………………….
(Principal Supervisor) Signature Date

Certified by:
Professor Ato Bart-Plange ................................… ……………………..
(Head of Department) Signature Date

**DEDICATION**

I dedicate this research work to the Ancient of Days, the Lord Almighty, the creator of the universe without whose intervention this project wouldn‟t have seen the light of day. I further dedicate this work to my two sons; Kwabena Opoku Tenadu and Kwadwo Wiredu Tenadu. Finally, I dedicate this Research Work to the late Dr. Emmanuel Ofori (Senior Lecturer) of the Department of Agricultural Engineering for his immense contribution and fatherly care before and during my studies at the Department. Blessed are the dead which die in the Lord from henceforth: Yea saith the Spirit that they may rest from their labours; **and their works do follow them** (Rev. 14:13).

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## ABSTRACT

Post-harvest losses of yams in storage continue to be a great disincentive to the farming business. Every season, quite a sizeable and significant number of yam tubers undergo deterioration in storage due to sprouting, weight loss, rot and pest damage. This work therefore sought to assess and test the post-harvest performance of two newly constructed yam barns (Circular and Rectangular barn) on the storability of two local yam varieties; "*Pona*" and "*Dente*". Two improved yam storage structures were constructed at Kasei; a farming village near Ejura. 480 yam tubers were marked and identified, weighed and stored in each barn with 240 tubers of each variety. The tubers were observed from 21st February, 2015 to 12$^{th}$ June, 2015 for the following parameters: Percentage tuber sprouts, Percentage tuber weight loss, Percentage tuber rots and Percentage rodent damage. Temperature and relative humidity in and outside both barns were monitored over the storage period. Results showed that, the average temperature and relative humidity in both Circular and Rectangular barns were 28.30°C and 66.7% and 28.9°C and 64.3% respectively while the ambient temperature and relative humidity recorded 31.2°C and 63.9 %, respectively. A survey was also conducted among farmers to find out the prevailing yam storage methods, farmers" knowledge on post-harvest losses and to ascertain the yam variety mostly cultivated by farmers. After the set period, the survey revealed three traditional storage methods as the most prevalent in the yam growing areas; Traditional barn, Burial in the soil and Heap on floor covered with straw methods. The traditional barn was found to be used by the majority (56%) of the farmers. Farmers attributed the cause of storage losses to a number of factors such as decay, injuries, pests, weight loss and sprout, of which majority (40.82%) indicated rot as their major concern. In addition, it was noted that about 52.0% of farmers cultivate *Dente* whilst 48% grow *Pona*. The storage study conducted however recorded the following cumulative results in both the circular and rectangular barns respectively: weight loss (*Pona*: 21%, 28.6%; *Dente*: 30.8%; 32.2%); tuber sprouts (*Pona*: 40.4%, 42.9%; *Dente*: 54.6%; 54.6%); tuber rots (*Pona*: 5.8%, 5.4%; *Dente*: 0%; 0.42%); rodent and insect damage (*Pona*: 6.9%, 1.7%; *Dente*: 0.63%; 0%) after 120 days of storage.

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# CHAPTER ONE

## 1.0 INTRODUCTION

Yam belongs to the specie *Dioscorea*. It is the main meal crop exceptionally within the yam zone of West Africa. It is one of the most important sources of carbohydrates to many people and as reported by Zannou (2006) and Akissoe *et al.* (2003); it is deemed a food security crop so far as West Africa is concerned. Amongst root and tuber crops in Ghana, yam production and yield is only surpassed by cassava (MoFA, 2013). The genus has been reported by Bailey *et al.* (1976), Sadik, (1988), Shanthakumari *et al.* (2008) to belong to the *Dioscoreaceae* family that involves true yams. According to Rudrappa (2009), the plant is a perennial vine cultivated for its large, fit for human consumption, underground tuber, which will develop as much as 120 kilos in weight and up to 2 meters in length. Yam plants are tropical crops and on no account grow at places where the temperature drops below 20$^oC$.

Despite the fact that more than 600 species of the tuber exist, only a few are important as staple meals within the tropics. These incorporate white and yellow varieties of the yam (*Dioscorea rotundata)* (*Dioscorea cayenensis*), water yam (*Dioscorea alata*), trifoliate and aerial types of yam (*Dioscorea dumetorum*) and (*Dioscorea bulbifera*) respectively as well as Chinese originated yam (*Dioscorea esculenta*) (Hahn *et al.*, 1987). West Africa contributes about 95% of world yam production with Nigeria the biggest single producer. In 2004, global yam production used to be about 47 million metric tons (MT) with 96% of this coming from Africa. Nigeria alone accounts for roughly 70% of world production (CGIAR, 2009). It is the second principal root and tuber crop in Africa with production reaching just under $^1/_3$ the level of cassava. It is a fact that more than 95% (2.8 million ha) of the present world used for yam cultivation is in sub-Saharan Africa, the place the where the gross yield is 10 t/ha.

Yam is an essential staple food crop in Ghana and is cultivated in every part of the country but mostly grown in the Guinea Savannah and transition agro-ecological zones. Ghana is the main exporter of yam, although it is the third biggest producer in the world, after Nigeria and Cote d‟Ivoire. On the average, the per capita consumption of yam has increased by 12% between 1997 and 2007 (Anaadumba, 2013). In a publication by FAOSTAT (2012) common day-to-day consumption of yam is set at 300 kcal per capita and it is the third major supply of energy in the Ghanaian food menu, accounting for 20% of whole caloric consumption. Yam contributed about 16% of the country‟s Agricultural Gross Domestic Product (GDP) during the period of 2005 to 2010 (Anaadumba, 2013). In addition, 6.3% of Ghana‟s arable land is used for yam farming (Otoo, 2005). Yam as an export commodity has gained prominence in the export business and has led to substantial gain in foreign exchange for socio-economic development of Ghana. Ghana in fact grew to be the second largest producer of yam in term of quantity in 2010 and has been the second largest producer in terms of price in 2001. In 2010, gross agricultural production value for yam was US$ 1,654,000 and accounted for the largest proportion of any crop (FAOSTAT, 1999 and COUNTRYSTAT Ghana, 2011). Having exported 20,841 metric tons of yams in 2008, but with growing international demand for yams coming from Europe, the U.S. and neighboring African countries, there is opportunity for greater production and export quantities (MiDA Report, 2010). However, most of the yam produced never reaches the table of consumers.

Osunde (2008) reports that causes of storage losses of yam tubers include germination, water being lost from plant parts, respiration, rot because of moulds and bacterial attack and destruction by insects, nematodes and mammals. Germination, water being lost from plant parts and respiration are routine plant growth functions which are based upon the environment in which the produce are kept. These plant growth functions affect the inside make-up of the tuber and ends up in destruction of the parts eaten and changes in nutritional characteristics. Storage losses in yam of the order of 10-15% after the initial three months and coming near 50% after six months storage has also been reported.

However, postharvest losses certainly at storage are a main task in yam production. The losses arise in different stages from production, after harvest handling, processing, marketing and distribution. These losses incorporate those in amounts harvested and overall acceptability of the tubers as a result of mechanical injury, pest damage, disorders caused by fungi and bacteria, and physiological processes such as germination, loss of water, and respiration. Estimated shortage of 10 to 60% of entire crop harvested was recorded (NAS, 1978). Weight reduction throughout the period of keeping yams in average storage barns can reach between 10-12% within the initial 3 months and thirty to 60% beyond 6 months. Loss of weight only accounts for 33 - 67% beyond 6 months of storage and this has been mentioned by Coursey (1967). In the Western parts of Africa for instance, this amounted to an annual loss of 1,000,000 tons of tuber (Akoroda and Hahn, 1995).

## 1.1 Problem Statement

Yam production has gained prominence for export in Ghana and has led to substantial gain in foreign exchange. It generates about 20 million dollars from 26, 000 metric tons of yam produced annually (Ghanaweb, 2014). Postharvest losses peculiarly at storage are a foremost undertaking in yam production (Maalekuu *et al.,* 2014). Available statistics indicate between 30 and 60 percent of yam harvested in Ghana are lost through postharvest storage. The income levels of farmers, processors, traders and other stakeholders are affected yearly as a result (Appiah, 2014). The major causes of post-harvest losses are weight loss due to evapo-transpiration intensified by sprouting, rotting due to fungal and bacterial pathogens and insect infestation (Bancroft, 2000). For an annual loss of one million MT of tubers from West Africa (Akoroda and Hahn, 1995), this translates into over US$700,000,000 annually which is of great concern to both farmers and national governments in the yam belt of West Africa.

## 1.2 Justification

There may be growing international demand for yams in Europe, the U.S.A and neighboring African international locations. “Ghana yam” is well recognized and desired internationally for its sweet taste. Domestically, yam is not only a most important source of income; however it's a staple crop principal to food availability (RTIMP Report, 2014). Owing to difficulties in propagation, the yam plant is close to extinction in a lot of indigenous areas of production (IITA, 2000). Alvarez and Hahn (1983) asserts that white yam cultivation in West Africa has been on the low side partly because the underground tuber which is the supply of food can also be the source of planting materials. Colossal portions of tubers and bulbils are committed to producing new vegetation, which otherwise would have been on hand for human consumption (Njoku, 1963).

The genus *Dioscorea* is so far the largest genus of the family and it may be very major in terms of coastal regions of West Africa the place where roughly 60 million humans receive more gigantic calories of vigour of about 800 kJ per day from it (Nweke *et al.*, 1994). The contribution of this crop to the dietary needs of man and economic gains accrued from its cultivation cannot be over emphasized (Iwueke, 1989). The Ministry of Trade and Industry is projecting to increase annual revenue from yam production by over 1400 percent, translating to about a billion US dollars in the next 5 years (Ghanaweb, 2013). Considering the area under cultivation, 6.32% of Ghana‟s arable land is used for yam cultivation. Yam makes a big contribution of about 16% of the value of Agricultural Gross Domestic Product (AGDP) (Otoo, 2005).

Sagoe (2006) also reported that Ghana‟s root and tuber exports generate about 75% of Government earnings and offers about 70% employment for the population. Yam is considered a food security crop in parts of Africa where they are mostly grown (Akissoe *et al.*, 2003 and Zannou, 2006). It is of much importance on the international market as an export crop as well as its diverse utilization (food, seed yam, flour and animal feed). The repute of the crop stays excessive with patrons, and dealers get an excessive fee in urban markets. However, yams remain somewhat under researched despite their ability to move farmers out of poverty in some of the world's poorest areas (IITA, 2010). It is obvious that the cost of preventing meals from going waste is more commonly not up to that of producing an extra quantity of food crop of the equal price and number. It therefore becomes imperative to find a more suitable and workable means of improving yam storage using relatively cheaper and available materials in construction of storage structures to hold the surplus harvest and make the crop available all year round.

## 1.3 Objectives

### 1.3.1 General Objective

The main objective is to assess the post-harvest performance of two yam varieties ("*Pona*" and "*Denteh*") under two improved storage structures.

### 1.3.2 Specific Objective(s)

The specific objectives were to:

a. Identify the best prevailing yam storage methods used by farmers.

b. Ascertain farmers‟ knowledge on postharvest losses in yams during storage.

c. Identify the type of yams mostly cultivated by farmers.

d. Establish the storage conditions (temperature and relative humidity) in the improved structures.

e. Determine the percentage weight loss after the set storage period of four months.

f. Determine percentage tuber rot, percentage pest damage and percentage tuber sprouts.

## 1.4 Significance of the Study

It affords farmers easy, cheap and convenient method of storing yams using locally available materials.

Identifies the specific yam varieties that can store for relatively longer period of time.

It assesses the performance of *Pona* and *Denteh* in the storage structure in terms of rots, weight loss, sprouts and pest damage

## 1.5 Hypothesis of the Study

The following null hypothesis was tested:

***Ho:*** The modified or improved Yam Storage barn can significantly reduce storage losses.

# CHAPTER TWO

## 2.0 LITERATURE REVIEW

In this chapter, several relevant literatures covering Botany of yam, Origin and Distribution of yam, Yam cultivation, Importance of yam, Curing of yam, Storage of yam, Types of yam storage structures, Extent of post-harvest losses of yams in Ghana, Yam weight loss at storage, Rotting, Sprouting, Pest damage, Methods of controlling post-harvest losses in yams have been reviewed in separate subheadings.

### 2.1 Botany of Yam (*Dioscorea spp.*)

Yam which is accepted for cultivation belongs to the monocotyledonous family *Dioscoreaceae* and genus *Dioscorea* (Coursey, 1967). It is a perennial plant with winding, mountaineering vines that grows in hot tropical climates (Swain, 2005). The aerial stem could also be tender, thorny or hairy and is also circular or rectangular in pass section. The leaves are alternate or reverse customarily coronary heart-shaped or furry. In designated species, bulbils (aerial tubers) are formed in the leaf axils (Osagie, 1992). Many of the vital yams species produce bulbils in the axils of the leaves, which have the morphology and appearance of a condensed stem, and in just a few circumstances are quite colossal and tuberous. Yams traditionally flower and the vegetation are small, and borne on long racemes, with female and male flowers separate and normally borne on separate crop plants (Ustimenko-Bakumovsky, (1983); Daisy, (1987); Onwueme, (1978); Degras, (1993). Of the 600 species of yams *(Dioscorea),* probably all have been tested as food plants. Some are harmless and useful, and some are poisonous and have been rejected or used only medicinally (Martin and Degras, 1978). Five or six species of yams *(Dioscorea alata* L., *Dioscorea rotundata* (L) Poir with *Dioscorea cayenensis* Lam., *Dioscorea esculenta* (Lour) Burk., *Dioscorea bulbifera* L., and *Dioscorea trífida* L.) can be considered the principal yams of the tropics and probably account for 95% or more of the yams eaten in the Tropics

(Martin and Degras, 1978). They are grown for their tubers or storage organs, which may be subterranean (e.g. *Dioscorea rotundata*, *Dioscorea alata*) or aerial (*Dioscorea bulbifera*), and serve a twin agricultural function as supply of meals and planting material (Coursey, 1967; Hahn, 1995). Yam tubers showcase dormancy, which prevents precocious sprouting (germination), prolongs storability and maintains meals first-class.

**2.2 Origin and Distribution of Yam**

According to Coursey (1967); Alexander and Coursey (1969); Ayensu and Coursey, (1972) ; Yams are grown in areas on three continents: West Africa, South America and Asia. The genus Dioscorea is considered to be among the many most primitive of the Angiosperms and used to be available and well varied in a part of the southern world at the end of the Cretaceous interval (approximately 75 million years in the past), and the early spread seems to have been via an Antarctic continent (whose climate was once wholly different in early geological times). The prevalence of *Dioscorea spp*. in southern Asia, Africa and South America already pre-dates human history and domestication of the exceptional species in these areas appears to have been through Aboriginal man. West Africa is the major cultivation zone, the place yam is a fundamental staple, producing about 93 per cent of the world's safe to eat yams, but the crop is also of tremendous value in constituents of eastern Africa, the Pacific discipline (including Japan), the Caribbean and tropical America (Appropedia,1987).

In a study conducted by Burkill, (1960), the family *Dioscoreaceae* is ordinarily one of the crucial oldest kinds of angiosperms and seems to have arisen within the Southeast Asia. The formation of the Atlantic Ocean on the end of the cretaceous interval separated historical and world species which due to this fact followed a divergent evolutionary direction. Desiccation of the core East within the Miocene period separated African and Asian species. However, their later evolutionary divergence used to be mild (Coursey, 1976).

The yam belt of West Africa lies between latitude 25$^{o}$N and 15$^{o}$S and comprises the countries Cameroon, Nigeria, Benin, Togo, Ghana and Cote d‟Ivoire (FAO, 2000). In Ghana, about 76 percent of yam production takes place in the Brong Ahafo, Northern and Eastern Regions, which account for 39%, 25% and 12% of total production, respectively, while the remaining 24 percent of production is distributed through-out the Upper West, Ashanti, Volta and Western Regions (Anaadumba, 2013).

Yam cultivation may be very intensive in the woodland-Savanna Transition, extending from the Northern parts of the Brong - Ahafo, Ashanti, Eastern and Volta regions, and in the Guinea Savanna zone the Northern parts of Ghana. The crop is also grown within the Sudan Savanna zone overlaying some constituents of the upper West and Upper East areas (Sam and Dapaah, 2009). Asante *et al.* (2007) also report that the Northern and higher West areas contribute tremendously to the whole yam production in Ghana. In West Africa yams are a principal supply of nourishment to millions of folks, as well as being a crop of prestige and cultural value (Coursey, 1967; Martin and Sadik, 1977). The main species in West Africa are white yam (*Dioscorea rotundata*) and water yam (*Dioscorea alata*). Yam ranks in second place to cassava which is regarded as the essential tuber crop in Africa. In addition, Africa can boast of producing virtually 98% of the world‟s yam. In all, a complete estimate of about 26,000,000 tons of yams is produced on the continent yearly (Onwueme, 1989).

### 2.3.0 Yam Cultivation

### 2.3.1 Land Preparation

Enhanced cultivation of yams requires some competencies on the growing conditions and cultural prerequisites of the crop. The following land preparation regimes are usually practiced in the tropics:

1. Weed off all grasses, shrubs and timber from the land.

2. Follow maximum tillage operations and include natural matter to make sure ample drainage, aeration, nutrients and room for tuber growth.

3. Plough and rotovate.
4. A quantity of limestone at 2-4 t/ha are added earlier than rotovating **(Agriculture.gov).**

Land cultivation may be done by either deep guide or mechanical approach. Cultivation targets to show over the topsoil and loosen the compacted soil under, to reap an excellent tilth for forming the hills or ridges, and provide a delicate, uniform medium the place storage root development will not be impeded. This can also be achieved with the aid of thorough plowing and harrowing finished a number of occasions relying on soil condition. Plant mulches, manures or other additives corresponding to lime or gypsum that have been applied to the outside, are blended into the soil for finest effect. Loosening up the soil raises the oxygen content material, which favours the progress of microorganisms that decompose natural and organic topic. Good land cultivation also aids control of weeds (lucidcentral.org). Yams require good pulverized free soil with high organic matter levels for convenient penetration and swelling of the tuber and therefore a shallow and compacted soil should be avoided for the production (Bamire and Amujoyegbe, 2005). For a farmland that has been cultivated earlier, two plowings and two harrowing are more commonly enough for yams. Nonetheless, plowing should be made deep seeing that yams need a deep loose soil. The flat bed and the ridged bed form show up to be most excellent to the other types of seedbed. When the latter is used, the ridges must be developed one meter or 60 cm apart. Within the case of sloping or rolling fields, construction of ridges will have to comply with the contour to reduce soil erosion (Root Crop Digest, 1987). Three types of planting methods are practiced: the setts could also be planted on the flat, they are also planted in trenches or holes, or they could also be planted on mounds, ridges or raised beds. The last method is the most widely used and the mounds can differ from about fifty cm high and might be twice as broad on the bottom, to virtually a hundred cm high and twice this width on the base. Within the smaller mounds one sett is mostly planted and within the better ones three or four, and even eight to 10 setts. More commonly, larger mounds are preferred

and the setts are planted in holes dug within the facets near the normal ground degree. They are planted deeply to hinder drying out of the young shoots and for that reason the pinnacle of the sett can also be positioned downwards. Sometimes, alternatively instead of separate mounds, ridges are used and the setts are planted alongside the perimeters of the ridges. Planting on the flat is best practiced in areas which are river flood plains, where the soil is deep and soft. In this procedure, the setts are planted in holes just beneath the soil surface (Appropedia, 1987).

Figure 1Yams growing on mounds

### 2.3.2 Soil Requirement

According to Root Crop Digest (1987), yams are upland plants and they usually will have to be planted in a good-drained area. Choicest yields are got from sandy loam and silt loam soil although ideal yields are also received from clay loam soils, notably those rich in soil nutrients. Stony and highly compacted soil should not be planted to yams. Soil-just right drainage is essential and for top-quality yields a deep well-drained sandy loam is required. On heavy, waterlogged soils the tubers are responsible to rot, even as on negative soils the susceptible root method is unable to obtain enough water or nutrients and minerals to provide reasonably-sized tubers (Appropedia, 1987). Yams, for example, require well pulverized, unfastened soil consistency with enough organic matter and nutrients, for effortless penetration and swelling of the tubers (Ezumah, 1986).

### 2.3.3 Water and Temperature Requirements

The distribution of yam production throughout the country is largely dependent on rainfall patterns. Yams require rainfall five months out of the eight months of growth in the field (Orkwo and Asadu, 1997). Yams most likely develop better in areas with annual rainfall levels from 1000 to 1500 mm and are well spread over six to seven months of the growing season (Anaadumba, 2013). Despite the fact that yams are relatively drought-resistant, they require plentiful moisture during their growing period, principally from fourteen to twenty weeks after planting when tuber bulking occurs swiftly. Irrigation will have to be furnished in areas where the dry season is longer than three or four months and falls inside the developing interval of the crops. They require temperatures ranging from $25^{o}C$ to $30^{o}C$ (Root Crop Digest, 1987).

### 2.3.4 Sett preparation

Seed pieces or setts are prepared a few days before planting. The roots are cut into pieces containing at least 2-3 eye-buds and weighing about 250 grams each.

### 2.3.5 Fertilization

The fertilizers suitable are 14-14-14 at the rate of 15g per plant and 0-0-60 at the rate of 2g per plant and 1kg of compost. The amounts applied are based on soil analyses.

### 2.3.6 Planting

Planting of seed pieces or setts could preferably be done late afternoon. The distance of planting is 1 meter between rows and 0.75 meter between hills.

### 2.3.7 Staking

As soon as sprouts emerge from the soil staking can be done with the use of split bamboos. Vines require stakes as support for better exposure of leaves to solar radiation. This practice is advisable because studies show that tuber yield increases. Stakes about 2.0-2.25 meter tall were placed per plant.

### 2.3.8 Weeding and cultivation

Weeds strive with yam plants for the already scarce nutrients in the soil, light and space especially during the early growth stages; hence, hand weeding can be employed as and when needed.

### 2.3.9 Control of pest and diseases

Furadan could be used at the rate of 0.5g/plant to control pest and diseases.

### 2.3.10 Harvesting

Harvesting is done when the leaves turned yellowish or brownish in color. This happens between 6 to 11 months after planting. Harvesting of the tubers is done using digging tools. Care must be exercised so as not to injure them while digging. Tubers are cleaned, accumulated and placed in plastic sacks depending upon tuber measurement (Perlas *et al.*, 2010). The tubers of yams may also be harvested once or twice during the season to acquire primary and secondary forms of harvest (Opara, 2003). Initial harvesting is done when the yam has attained about six months after planting. In Ghana, it is done by using a cutlass to detach the tuber from the vine and roots at the proximal region.

Here, the harvester must exercise great care not to sever the roots to ensure continuous growth. The tubers harvested from the second harvest are not used as food but rather as seed yam because they are fibrous and unpalatable.

**2.4 Importance of Yam**

Yams are a foremost staple food and source of carbohydrate across West Africa. Also, they are fundamental medicinally and have ritual and socio-cultural importance (Hahn et al., 1987). In Ghana, it is used sacredly in traditional festivals such as Ohum by the people of Akyem Abuakwa and Odwira by the Akuapems; all in the Eastern part of the country.

Yam is ranked as one most important source of dietary calories in Côte d"Ivoire, Benin, Ghana, and Nigeria. The crop also makes a substantial contribution to protein in the diet, ranking as the third most important source of supply. Consequently, yam is fundamental for food protection (as mainstay for no less than 60 million individuals) and also for revenue generation; 31.8% of the population in Nigeria and 26.2% in Ghana depend on yams for food and income security. As a vegetable crop with numerous uses, yam may also be boiled, roasted, grilled or fried and served sliced, as balls, mashed, chipped and faked. Contemporary tubers will also be peeled, chipped, dried and milled into flour (IITA, 2012). In South-eastern part of Nigeria, the cultivation and consumption of yam dates back a few centuries. In this locality, yam is a totem of masculinity and the center of annual harvest celebrations; it is usually a calendar crop round which the farming season and the annual festival revolve (Osunde, 2008).

The tuber form of yam boiled and eaten as *"Ampesi"* especially the "new yam" is preferred by most consumers in Ghana since it is a seasonal crop. Yam can be boiled and pounded into fufu, roasted or fried. Yams are major source of carbohydrate, fibres and low level fats which makes them good dietary source (Grindley *et al.*, 2002; Jaleel *et al.*, 2007) and also processed in to different staple foods, semi-finished and finished product (Coursey, 1967).

Yam can also be processed into flour which has the potential of serving as a primary ingredient in the production of bakery products, porridge, pudding and other meals (Tortoe *et al.*, 2014). Yams have Medicinal properties (Kelmanson *et al.*, 2000; Jaleel *et al.*, 2008b). Several species of *Dioscorea* are amongst the principal sources of diosgenin, which can be converted to medicinally important steroids (Jaleel *et al.*, 2007). Human steroids hormones, such as cortisone, estrogen, progesterone, pregnenolone and testosterone are extracted from yams. They are also used as a base for human contraceptive pills (FAO, 2003). There are a few reviews suggesting that diosgenin-rich food sources reminiscent of fenugreek seeds and yam tubers contribute to anti-diabetic effects in experimental items (Basch *et al.*, 2003; Omoruyi, 2008).

**2.5 Curing of yams**

In order to reduce further weight loss and rotting in harvested root crop plants, they first have to be cured to permit suberin formation at the sites of bruises. Bruises sustained throughout harvesting and handling stages can make the tubers prone to damages. In view of this, curing of yams is advocated before they are stored. It can also be comprehensive below tropical environmental situations or in a managed atmosphere. Often, matured tubers of yams are cured with the aim of drying the tubers within the solar radiation for a couple of days (Opara, 2003). Yam tubers have to be safely cured as soon as feasible after harvest to enhance the formation of a hard cork layer. The cork layer surrounding the roots and tubers is meant to function as a barrier against bacterial and fungal invasion. Curing will have to be applied near the position where the tubers will be saved to scale down handling after curing. The approach is applied for four to seven days at temperatures of 32°C to 40°C and a relative humidity of 85% to 95% (FAO, 1998). Farmers attain these conditions in two ways:

**Above floor:** Yams are cautiously piled on the ground and covered by using a layer of grass as a minimum 15 cm thick and finally a canvas tarpaulin or jute bags are used to cover the entire pile (figure 4.1). Plastic sheets should no longer be used and the curing pile must now not be exposed to direct daylight. The duvet must be removed after four days (Knoth, 1993).

**Pit-curing:** this can be a generally used system in the neighbourhood of Nigeria. It includes a pit, roughly 2.5 x 1.5 x 1 meter with the bottom spread with sawdust or dry grass. The yam tubers are positioned on this lining and then covered with a thin layer of soil. This treatment spans a period of about two weeks after which the tubers can also be taken for storage (FAO, 1998).

## 2.6 STORAGE OF YAM

Yam has a seasonal production that makes mandatory its storage for use as food or seed (Kouakou *et al.*, 2010). In reference to a report by Ohiagu (1986), since all that is produced cannot be consumed instantly, there may be always the necessity for sufficient and effective storage facilities to save the surplus crop from deterioration and waste. Storage serves a threefold function in any human society. These are to make sure consistent availability of produce and stable costs of produce, thereby decreasing the seasonal fluctuations of market prices; to allow farmers and producers unload their produce at strategic occasions for satisfactory market prices; and to eliminate or curb quantitative and qualitative losses, thereby making certain that viable seeds are on hand for use within the next planting season (Ofor *et al*., 2010).

Root and tuber crop plants still have life in them after they have been harvested and losses that arise during storage come up customarily from the nature of their body. The principal factors of loss are associated with mechanical harm, physiological situation (maturity, respiration, water loss, sprouting), disorders and pests. To ensure effective storage of root and tuber plants, these essential causative motives ought to be competently understood and, where right, be thoroughly managed, deliberating the socio-monetary factors which pertain to the areas of production and selling (FAO, 1998). The types of storage structures used are influenced by way of more than a few considerations. These comprise local weather, intent of the yam tubers in storage and socio-cultural points of storage (symbols of prosperity and use for cultural functions). However, the storage structures are additionally influenced with the aid of the type of building substances on hand and the resources of the farms, in detail, the supply of labour and capital (FAO, 1990). Sometimes, yams are left unharvested. But essentially the most usual practice is to harvest the yams and store them in a precise constitution. At harvest time, many yams are right away eaten or taken to market. However most are saved to be eaten or marketed throughout the 5 months or longer following harvest. One of the vital harvested yams might be used as planting setts for the following season and is also stored for as long as 6 months (IRETA, 1987).

Root and tuber crop plants contribute immensely to general meals requirements among city and rural dwellers, exceptionally for poorer communities. With rising urbanization in lots of areas, there is a growing need to store and transport newly harvested produce but perishability is mainly a challenge because of the excessive moisture content of tubers ( 60% to 80% when recent) (http://www.gtz.de/post_harvest).

**2.7.0 TYPES OF YAM STORAGE STRUCTURES**

Harvested crops are often slow to reach the markets or the consumer due to lack of immediate transportation from the farm sites. The need for lenghty storage also arises due to the seasonal production of these crops which must be reserved for food when the crop is out of season and becomes the most sought after. It is also used as seeds for planting in the farming season.

Quite a lot of common and contemporary storage procedures are practiced in the country relying on technical know-how, amenities available, price, climatic changes at the time of storage, danger of destruction to crops by pest and the wide variety of farm produce. Even though modern strategies are being developed for strong storage of those farm produce in huge quantities, most farmers nonetheless depend upon the average approaches for the reason that these new tactics usually are not within their attain (Etejere and Bhat, 1986).

### 2.7.1 Indigenous Yam Storage Structures

A number of storage methods are utilized by farmers in West Africa (FAO, 1998). Natural storage structures incorporate pits, trench silos, and heaps in the area but these are elaborate to manage i.e to avoid pest attack and provide ordinary inspection of tubers (http://www.Gtz.De/post_harvest). There are a few typical inexpensive storage ways and structures for yam tubers. The most normal of them include allowing the tubers to remain in the soil until required, storage beneath tree shade, yam barns, underground structures similar to pits and ditches, mud buildings, thatched huts and cribs. The storage constructions are of distinct styles and sizes relying on the ability of the farmer locality and cultural practices. The construction materials are in most cases wood, ropes, palm fronds, guinea corn stalks, and laterite. (Osuji, 1985; Cooke *et al.,* 1988; FAO, 2004). As reported by Opara (1999), there are a couple of average structures and methods used for keeping yam namely: (a) allowing the tubers to remain within the soil unless needed, (b) the local yam barn, and (c) Subterranean compartments

### 2.7.2 The Yam Barn

In West Africa, the yam barn continues to be the commonest storage infrastructure for yam storage (FAO, 1998). It is the predominant common yam storage structure within the main producing areas (FAO, 2003). Barns are probably pitched in shaded areas and built so as to facilitate ample ventilation at the same time guarding tubers from water outburst and pest assault. Barns are made of an upright picket structure to which the tubers are hooked up (Fig. 2). Tubers are stringed to a line at every terminal hanging horizontally on poles one to two meters high. Local storage facilities up to four meters in height are exceptional. Relying on the quantum of produce to be saved, component frames can be two meters or extra in dimension. The ropes are normally high in fibre. However, in south eastern parts of

Nigeria, they are manufactured from the raffia acquired from high part of Oil Palm trees. A lot of farmers have everlasting facility, which needs yearly repairs for the duration of the harvest for that particular year. On these occasions, trees which are still growing serve as the upright posts, and are pruned from time to eliminate sprouting parts. Oil palm branches and other materials are used for provision of shade. The sprouting vertical tree stands additionally shades the tubers from immoderate sun warmth and rain. Using open-sided cabinets created from tree poles which are still germinating, poles of bamboo tree or wood have been endorsed to permit cautious dealing with and handy monitoring and evaluated with tubers that are attached to poles which are able to check injury to tubers and thereby preventing rotting (Bencini, 1991). Barns are powerful for yam storage for the period of the dry season, however once the wet season starts, tubers stored in barns are inclined to deteriorate swiftly, with the continuously moist atmosphere enhancing the rotting of the tubers and the skeletal framework of the barn. Additionally, with each and every rain, disorders unfold from rotten tubers to neighbouring healthy yams mainly those within the scale back tiers. Accordingly, farmers who use barns hold their yams until the initial part of the wet season, at the same time the rest of the yams meant for consumption are moved indoors and stored on the floor or on shelves. Right here they are risk-free from the rains and also pilferage, which is frequent throughout the months of yam shortage following the planting season. The development of yam barns for use over a few years also requires excessive capital input (wood for construction) (Ofor *et al*., 2010).

Figure 2 A typical traditional yam barn

Figure 3 The inside of traditional yam barn

### 2.7.3 Field Storage in the ground until required

Yams attain maturity, generally on the beginning of the dry season, when vegetative growth stops, the leaves turn yellow and lots of the dry matter of the yam vine is translocated into the tuber which then enters a resting or dormant stage (FAO, 1998). This stage of physiological maturity in general occur some eight to eleven months after planting and the yams are then in a position for harvesting. In some communities, the tuber will also be left in the ridges or mounds for as much as four months as a type of storage, based on the particular yam variety. This storage procedure as a rule does now not require any fee in erecting a store. There is nonetheless no safeguard from pests (insects like termites, nematodes, rodents and others). Furthermore, the farms are not able to be used for other purposes while the storage period lasts (Ofor *et al.,* 2010). The practice of allowing the tubers to remain in the soil unless needed is the easiest method of storing carried out with the aid of rural small-holder farmers. When implemented directly at the farming area, this kind of keeping harvested crops does not allow the farmland to be used for cultivation of further crops (FAO, 2003).

### 2.7.4 Storage in Trench Silos

Yam tubers are additionally stored in layers inside trenches. They are then blanketed with dry grass followed by a layer of soil. The trenches are typically constructed in places where the soil is dry, with the intention to preclude sprouting and decay (Etejere and Bhat, 1986). In yam fields which are placed some distance from human settlements, the farmers make silos in or on the perimeters of the fields. This saves labour which is scarce throughout the harvest duration and likewise avoids wasting labour crucial for transportation in the course of harvest. This form of storage which is traditionally practiced in areas with distinct dry season is done through digging a pit whose dimension can conveniently accommodate the anticipated yam harvest. The dug-out hole is bedded with dry grass materials or an equivalent material. The tubers are consequently saved within packed dry grass materials either lying on the ground or allowed to stand upright with individual tubers lying side by side, and the tip going through downwards vertically. The trench silo may also be constructed underground or with a part of the storage room on top of the ground. It is mostly blanketed with straw or an identical material. However, the usual way doing it is that a layer of earth can also be added. The observed difficulties related to these storage systems are essentially lack of ventilation and direct contact of the tubers with each other.

This makes the stored produce to heated up and consequently lead to the formation of rot. The closed nature of the trench silo additionally does not allow typical checking of the saved produce. Additionally, the silo serves as good habitat for rodents, with a corresponding injury to the stored produce (Ofor *et al*., 2010). Harvested tubers can be kept in subsoil compartments akin to clamps, ditches and pits. The above listed methods are appropriate for restricted keeping durations; particularly the varieties which mature early are most likely harvested earlier than the latter part of the wet months. For the period covering building of trenches, the laterite dug out is used to build a short wall to surround the part. The atmospheric condition in the environment for storing produce is regulated by placing chopped plant materials over the ditch, clamp or pit. For these constructions, air flow and pest destruction of harvested produce is a foremost drawback, and remains problematic in checking out the stored tubers (FAO, 2003).

**Figure 4 The Trench or Pit Storage of yam**

### 2.7.5 The Heap/Top of Ground Method

Under this method, yams are carefully packed on the soil surface and covered with a layer of grass at least 15 cm thick and lastly a canvas tarpaulin or jute baggage are used to wrap the whole pile (FAO, 1987). Plastic sheets must no longer be used and the tubers under curing should no longer be exposed to direct sunlight. The cover should be eliminated after 4 days (Knoth, 1993). The heap- on- the ground method involved identifying a welldrained flat ground spot. Dried maize stalks were collected and placed on the ground. The yam tubers were then piled upright in a triangular form in a heap on the dried maize material. Dried maize stalks were then used to cover the pile of tubers (Nyadanu *et al.*, 2014).

**Figure 5 The Heap Method of Yam Storage covered by dried vines and twigs**

### 2.7.6 MODERN METHODS OF YAM STORAGE

### 2.7.7 Gamma Irradiation

Researchers have worked on several ways and systems to reinforce yam storage. Specific intensities of gamma irradiation supplied some technical benefits for storing yam tuber to enable users to utilize them in the fresh state (Adesuyi and Mackenzie, 1973; Bansa and Appiah, 1999; and Vasudevan and Jos, 1992).

### 2.7.8 Improved Storage Structure

The use of enhanced yam storage structures has been stated by some authors (Hahn *et al.*, 1987 and Adejumo, 1998). The enhanced barn is rectangular in form with various dimensions. The floor is cement cast and raised above the ground stage to preclude pests from having an entry route to the barn. The walls are developed of plastered concrete 1m above the bottom and the remaining is predominantly made of fowl wire mesh interwoven collectively by welding mechanism (Adejumo, 1998). The roof is corrugated aluminium sheet, raffia mats or grass. Inside the building are a number of picket cabinets which have cubicles and the yams are organized on these shelves. The actual benefit of this storage unit is that inserting the tubers on the shelf consumes less time and labour, presents ample air flow (by means of the wire mesh system) and the gap between the wall and the cabinets ensures easy movement when inspecting the tubers for possible damages (Hahn *et al.*, 1987 and Adejumo, 1998).

### 2.7.9 Cold Room Storage

Cold room storage at 15$^{o}$C is being tried at research stations. However, this method has been found to be expensive for the traditional farmer (Etejere and Bhat, 1986). Managed and regulated temperature storage used across the world for the keeping of perishable merchandise and farm produce could also be used to extend the life of yam tubers. Temperatures of round 20$^{o}$C have proved to be effective in preventing sprouting and slowing down respiratory activities within. However, yams do not have to be stored below 15$^{o}$C else chilling harm will occur (FAO, 1985). Nonetheless, there is no authentic information on invaluable results on (CA) controlled atmosphere usage or technology and also on large scale storage of major yam cultivars (Opara, 2003).

### 2.7.10 Electronic System Control Method

Literature search has unveiled rather a small quantity of electronic controlled food storage systems in evaluation to model-based ones. The open nature of the storage unit makes it possible for interference of the atmosphere in the storage approach. The controller consists of a fuzzy logic and neural network system. The aim is to manage the storage temperature and relative humidity above all, at the same time monitoring the carbon dioxide trend of increase inside the storage atmosphere (Oluwo *et al.*, 2011).

## 2.8 Post-Harvest Food Losses

The storage of yam is challenged by countless issues and is as a rule beyond the usual farmer‟s control. Postharvest losses constitute a major trouble and have been estimated with the aid of various authorities that 20% to 80% of harvested yams are lost after harvest. Meals loss and food waste add to make a contribution to put post-harvest losses. Postharvest food Loss (PHFL) is outlined as measurable qualitative and quantitative meals loss along the supply chain, beginning from the time of harvest until its consumption or other final consumers (De Lucia and Assennato, 1994; Hodges *et al.*, 2011). Post-harvest losses can occur either as a result of meals waste or because of inadvertent losses along the way in which they are distributed or supplied. As a consequence, food waste is the lack of wholesome food due to human action or inaction comparable to throwing away spoilt produce, not taking in available food earlier than its expiry date, or taking serving sizes beyond one‟s potential to consume. Food loss however, is the inadvertent loss in food variety on account of infrastructure and administration obstacles of a given meals value chain (Jaspreet and Regmi, 2013).

Food and Agriculture organization of U.N. estimates that about 1.3 billion plenty of meals are globally wasted or lost per year (Gustavasson *et al.,* 2011). A cut-down on these losses would cause a hype in the quantity of meals available for human consumption and increase global food security, a growing quandary with rising food prices because of developing client demand, increasing demand for biofuel and different industrial utilizations, and elevated climate variability (Mundial, 2008; Trostle, 2010). The present world population of 7.2 billion is anticipated to increase to 9.6 billion by 2050 (UNNC, 2013), further adding to global food availability issues. This increase translates into about 33% more human mouths to feed, with the finest demand progress within the poor communities of the world. According to Alexandratos and Bruinsma (2012), meals supplied would necessitate an increase by 60% (estimated at 2005 food production levels) with the view of meeting the meals that would be required in 2050. Food availability and accessibility will also be accelerated by way of growing more food, bettering distribution, and lowering the losses. For that reason, a downward review of post-harvest food losses is a crucial element of making sure future global meals are available.

**2.9 Extent of Post-harvest Losses of Yams in Ghana**

According to a report by Alliance for Green Revolution in Africa (AGRA) carried out in 2013 with the aid of The Urban Association Limited (TUAL) on Post-harvest losses of chosen food crops in eleven African countries, as much as 60% of yam produced in Ghana, for example, does not get to the end user. (AGRA, 2013*)*. Yam tubers are perishable produce (Alhassan, 1994). Furthermore, post-harvest losses for yam in Ghana amount to

24.4% of production, despite the Ministry of Food and Agriculture‟s goal to reduce these losses to only 12% by 2012 (MoFA, 2007). It was observed that large quantities of yams are lost annually to the detriment of producers, distributors, and consumers. The major causes of post-harvest losses are weight loss due to evapo-transpiration intensified by sprouting, rotting due to fungal and bacterial pathogens and insect infestations (Bancroft, 2000). Though agriculturists generally believed that tubers of yam store well, that is not the case since candid observations showed that postharvest losses are heavy (Asiedu & Alieu, 2010). From Opara (2003), post-harvest losses occur at quite a lot of levels from production, postharvest handling, advertising, distribution and processing. The bulkiness of yam tuber, its chemical composition and moderately high water content predispose it to degradation during long-term storage (Asiedu & Alieu, 2010). The production of yams in Ghana is very constant and sufficiently large enough to meet home (Ghanaian) consumption and overseas demand (the biggest international market is the U.S.). Nonetheless, despite a well-headquartered and growing market in the U.S. and greater than considerable emanating from Ghana, the U.S. Market for Ghanaian yams has taken a downward trend. With spoilage ratings often pegged over 50%, each importer is facing the same amount of losses, resulting in an extreme disruption to the market: unsold product in Ghana, insufficient export to the U.S. Market, and volatile prices. Fiscal losses are noticeable in any stages of the supply chain from the growers in Ghana right through to the consumer (Olu, 2005). According to Rees (2012) on farm storage losses for late season harvests are 10- 50% and at retail, about 10 – 20% are reported as damaged whilst 4 - 40% are recorded as rotten. Total food losses prevailing in Sub-Saharan Africa are estimated to be valued at four billion dollars per year, an amount which will feed forty eight million humans (FAO, 2013). These incorporate quantitative losses and tuber quality, coming up from tuber bruises, pest attack, fungi and bacteria disorders, and growth activities like germination, water loss, and breathing (NAS, 1978).

### 2.10.0 Yam Weight loss at Storage

Released literature associated with research on weight loss of yam tubers in storage structures has been few (Ezeike, 1984).

### 2.10.1 Effects of Temperature and Relative Humidity on weight loss

These three major conditions are necessary for effective yam storage: free passage of air, lowering of temperature and regular checking of produce. Free passage of air does prevent moisture condensation on the surface of the tuber and aids in getting rid of the heat generated as a result of respiration. Temperatures which are on the low side is fundamental to losses emanating from respiratory activities, germination and deterioration; nonetheless, cold storage has to be kept constant around 12 to 15$^{o}$C under which growth destruction like those associated with extreme coldness occurs. The water vapour within the interstitial spaces in the yam tissues exerts a water vapour pressure, which pressure is a factor of the quantity of free water contained within the tissues and its temperature. The speed at which water is lost from newly harvested tubers depends upon the difference between the water vapour pressure inside the tubers and the water vapour pressure of the encircling air, with moisture moving from the high pressure area to the low side. If there is a significant change between the temperature of the produce and the surrounding air, temperature becomes the dominating effect on water vapour pressures, whereas when both are at an identical temperature, it is the quantity of water vapour that has the most giant result. It, as a result, follows that to reduce water loss from high moisture content material, the produce should be stored in atmospheres which have comparable water vapour pressures (FAO, 1998). Regular inspection of harvested food material is fundamental in identification and removal of germinated tubers, deteriorated tubers, and to watch whether rodents are present as well as different pests. In most cases, tubers must be blanketed from excessive temperatures and furnished with excellent air flow for the duration of storage. The storage atmosphere ought to moreover obstruct the onset of germination (breakage of dormancy) that accelerates the rate of loss of food constituents in yam tubers and their further shrinkage and rotting.

Matured yams and yams used for planting have identical keeping necessities (Opara, 2003). The advocated storage temperature is within the range of 12°C - 16°C. Most desirable stipulations of 15°C or 16°C at 70 - 80% RH or 70% RH have been advocated for sun dried yam tubers (Martin, 1984; McGregor, 1987). The permeability of the skin of the tuber is a factor for determining its maturity and is a very important factor in terms of the rate of respiration. The periderm of freshly harvested immature tubers is most permeable and for this reason permits larger amounts of respiration than similarly harvested mature tubers (FAO, 1998). A decline in temperature, although this is just a few degrees Centigrade, prolongs dormancy. On the opposite, an upward thrust in temperature reduces dormancy (Passam, 1982). Relative humidity additionally has similar outcomes. Excessive humidity for example on the commencing of the rainy season, promotes germination. Low humidity alternatively, prolongs dormancy (Wickham, 1984). Consequently loss of weight in Yam will also be attributed to higher respiratory activities (Passam, 1982).

### 2.10.2 Effect of sprouting on yam tuber weight loss

According to Passam *et al.* (1978), one of the factors of storage losses of yam tubers comprises sprouting. As quickly as dormancy is eliminated and sprouting starts the pace of dry matter loss accelerates exponentially due to the fact that the formation of sprouts requires vigor, which is drawn from the tubers' carbohydrate reserves. The rate of water loss additionally raises and if this persists the tubers dry out allowing pathogens to penetrate the tuber. This can possibly cause severe damage if not whole loss, making continued storage relatively impracticable (FAO, 1998). Physiological losses due to sprouting and respiration account for a lot of the weight loss in storage. These also fritter away food reserves and exhaust planting materials. Sprouting customarily makes the yam bitter and unpleasant to taste (FAO, 1985).

### 2.11. Effects of Rot Pathogens on yam quality and storability

Tuber rot brought on by the activities of various pathogens is one of the most important causative agents of loss throughout the storage of fresh yam tubers. The fungi inflicting rot are most likely lesion pathogens. They may be able to only actively penetrate the tuber via lesions, cuts, holes bored through nematodes or the place where rodents have bitten the tubers (Coursey, 1967). Traditionally only one sort of fungus penetrates the tuber in the beginning and is then followed by others. There are more than a few types of rot on yam tuber and depending on the consistency these can be categorized into "dry", "watery" and "smooth" rot (Centre For Overseas Pest research, 1978). Rot can infest most effective parts or the whole tuber. "Dry" rot cannot be determined externally. Rot causes alterations in consistency and flavour. Ordinarily the tubers are no longer suitable for consumption causing huge loss in market worth. Studies have shown that fungal rot is the greatest cause of tuber loss in storage (IITA, 1993; Cornelius and Oduro, 1999; Amusa *et al.*, 2003). The largest postharvest losses in yams result from microbial attacks (Ghosh et *al*., 1988).

Several species of *Fusarium* are able to spoil yam tubers, but *Penicillium sclerotigenum* is one of the well-known and very specific spoilers of this plant (Yamamoto *et al.*, 1955). Losses affecting the produce qualitatively and those which happens when the disease influences the outside of the produce do not always influence the intrinsic high-quality or variety of the commodity but makes the crop less appealing to the purchaser or customer out there (FAO, 1998) and such affected tubers does not store for long. Reports from Africa revealed that the most common yam rots there include *Aspergillus* rot caused by *Aspergillus niger* V. Tieghem (Ogundana *et al*., 1970; Ikotun, 1983), blue green mould rots caused by

*Penicillium* sp. (Adeniji, 1970) and *Botryodiplodia* rot caused by *Botryodiplodia theobromae* Pat (Adeniji, 1970); Ogundana, 1983; Aderiye and Ogundana, 1984). Two forms of nematodes are commonly observed in yam tubers, the lesion nematode (*Pratylenchus coffeae*), and the foundation-knot nematode (*Meloidogyne spp.*). Most effective lesion nematode (*Pratylenchus*) is of importance so far as storage is concerned (IRETA, 1987). Morse *et al.* (2000) demonstrated that proper control or management of injury inflicted on harvested yam produce on the field prior to storage could be very fundamental to minimizing the incidence of fungal disorders of yam for the period of storage.

### 2.12 Pest Damage

White yam tubers can be stored for several months under sufficient storage stipulations and under constant surveillance. However, there are considerable losses using common yam storage structures because of bacterial and fungal rotting, rodent damage, sprouting and other reasons together with theft. As an outcome, over a million tons of tubers may also be missing yearly throughout storage in West Africa. Rodents and other pests together with insects damage to the tubers, which are much more prone to rotting once they have gotten injured through pest organisms (GTZ - http://www.Gtz.De/post_harvest). Rodents like rats and mice, and from time to time other mammals, destroy yams during the period of storage, inflicting loss. Insects may also make a contribution by means of their feeding. Mealy bugs and scale insects depletes the food reserves in the tubers, normally leaving them too vulnerable to regrow when used as planting sets (FAO, 1985). Rats will without problems consume stored yams in the event that they find the shop easy to enter and if they have got plenty of cover where they can take shelter (IRETA, 1987).

### 2.13.0 METHODS OF CONTROLLING POST HARVEST LOSSES IN YAMS

So as to meet the food demand challenges of our growing economies, and to acquire sufficiency and security in meals production, food production has got to be matched appropriately with their protection from spoilage and rot organisms in times of transit or storage (Shukla *et al.*, 2012). In order to control these organisms and the deterioration or rots associated with them, several manipulative skills have been put in place. The underlisted are some of the control methods:

### 2.13.1 Curing

In line with Okigbo (2004), curing naturally promotes thickening of the tuber dermis. It enables cure of wounds and abrasions sustained throughout harvesting by means of suberin formation at the sites where wounds have been created, and subsequent development of periderm or corky layer over the injuries. As a consequence, the corky layer callouses-off infective agents and prevents water from moving out of the wounds.

### 2.13.2 Biological control of rot organisms

The control of plant diseases biologically involves the practice whereby the growth, survival and undertaking of a pathogen is reduced via the agency of every other living organism and with the outcomes that there is a cut-down in the prevalence of the disease brought on by using the pathogen. In step with Okigbo (2004), soil-derived non-pathogenic strains of *Bacillus subtilis* and *Trichoderma viride* are powerful biocontrol agents which manage post-harvest and storage rots of yam tubers. A single usage of this bio-control agent preserved tubers in storage for as much as 6 months (Okigbo and Ikediugwu, 2000).

### 2.13.3 Chemical Control

Artificial pesticides have long-standing fame in agriculture. Their use has been credited with improving yield of agricultural plants and maximizing the returns on funding on farm capital (Bennett, 2005). Artificial pesticides have large spectrum of utility within the field, transit or store.

Control of rots in yam tubers was tried with huge advantages with bleach (sodium hypochlorite), borax, captan and orthiophenylphenate, naphthalene acetic acid, maleic hydrazidine, lime and gin (Okigbo, 2004; Okigbo and Nmeka, 2005). However, these chemical compounds are heavy-duty chemicals whose disadvantages are ample in science literature (Enyiukwu and Awurum, 2013). Chemical pesticides have further negative aspects of accumulation within the ecosystem and often induces resistance of pathogens to pesticide effects (Okigbo and Ikediugwu, 2000; Okigbo, 2004). There is additionally the issue of lack of expertise amongst lots of the farmers in terms of safe handling of pesticides.

Judging from these lethal disadvantages, the scientific community should endearvour to focus attention on friendly alternatives.

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### 2.13.4 Low Temperature Control

Low temperature storage also slows down the metabolism of pathogens and so frequently arrests rotting. However, the pathogens are rarely killed, so when the produce is returned to ambient temperatures, the rotting may recommence rapidly. By lowering the rate of a myriad of biochemical and physiological processes and reactions that ultimately lead to sprouting, low temperatures are able to prolong the storage life of yams by simply delaying sprouting. Several investigators have shown that the storage lifespan of sound matured tubers can be increased by as much as four months by temperatures 16-17$^{o}$C (Okibo, 2003; Okibo and Osunde, 2003). Attention is beginning to be shifted to low temperature control as a practical alternative to deterioration of harvested produce. As a post- harvest loss curbing measure, a Perishable Cargo Centre has been constructed at Kotoka International Airport which is funded by the Ghana compact of the Millennium Challenge Account. However, there still remain some major impediments to its wide spread adoption by the average Ghanaian farmer such as technical expertise of farmers, unreliable power supply by the Electricity Company of Ghana, inaccessibility to electricity supply, the problem of chilling injury and the cost of managing electricity power generators.

### 2.13.5. Genetic Control

The use of botanicals has not been effective against microbial rot in yam. On the other hand, use of chemicals is expensive and, thus not affordable by small-scale farmers. Also, there are concerns about health hazards and environmental pollution. Moreover, use of chemicals and botanicals has been associated with a number of deleterious and physiological effects on plant tissues (Amusa and Ayinla, 1997). Breeding for resistance to internal rot in yam has been regarded as the most economical and environmentally friendly way of controlling the disease. As reported by Nyadanu *et al.,* (2014), natural host plant resistance to microbial rot in yam offer no risks or threat to the user and environment.

### 2.13.6. Natural Plant Extracts (Botanicals)

There are several local plant species whose extracts or biocides have proved to be efficacious in protecting yam produce before and after harvest. The most popular among them is the neem (*Azadiracta indica* A. Juss). Formulations of extracts of *A.indica* include Water Dispersible Powder (WDP), Dust Preparation (DP), Emulsifiable Concentrate (EC), Neem Seed Water Extract (NSWE) and Neem Cake Water Extract (NCWE). Others include *Zingiber officinale, Ocimum gratissimum, Xylopia aethiopica, and Piper guineansis.* Local availability, little or no toxicity to humans and simple methods of preparation are some of the advantages derived from usage of natural plant products (Okigbo, 2013).

# CHAPTER THREE

## 3.0 MATERIALS AND METHODS

### 3.1. Site of Experiment and Location

The experiment was carried out at Kasei, a farming community in the Ejura – Sekyedumasi District of Ashanti region. The District is found in the Northern part of Ashanti Region and is linked to the North by Nkroanza North and Atebutu District of the Brong Ahafo Region. It is also bounded on the East by Sekyere Central, to the South by Sekyere West and Mampong and to the West by the Offinso North District, Nkoranza North and Nkoranza South Districts. The District stretches over an area of 1,782.2 sq km which is about 7.3% of the total land area of the Ashanti Region (MoFA, 2013).

### 3.2 Description of Improved traditional storage structure

Two modified traditional yam barns were designed and erected under a teak tree (*Tectona grandis*), where sufficient shade and ventilation were available. They are in the shape of rectangular and circular yam barns. The yam barn frame is made up of vertically erected wooden poles from *Borassus flabellifer* of height 4m and set at a distance of 1m to each other. These wooden poles had been stabilized with the aid of attaching horizontal poles to them. The Circular barn (Figure 7) measures 4.0m diameter and height 2.0 m respectively. The rectangular barn (Figure 6) was dimensioned 4.0m × 3.0m × 2m also representing the length, width, and height respectively. Each barn was raised 1m high above ground and the base made with wooden boards. The columns of the barns were fixed into holes locally knitted thatch made of dried grass stalks of *Imperata cylindrica* (Spear grass) were wound round „neem‟ rafters at the top to serve as the roof. The enclosure walls were made of wooden boards from common tree specie. There was a small opening between the roof and wall which is netted to enable air flow thereby leading to a decline in ambient temperature within the barn. The nets also guard against thieves, birds and rodents. Inside the barns are shelves

(Figure 8) on which the yams are stored. The entrance has a door secured with a padlock (Figure 9).

**Figure 6 The Rectangular type of Yam Storage Structure**

**Figure 7 The Circular type of Storage Structure**

**Figure 8 The internal shelves of the barn**


**Figure 9 Other features of the new yam storage barn**

### 3.3 Experimental Work

The experimental work spanned the period 21st February, 2015 to 12th June, 2015, thus 120 days of storage. The experimental materials were the two varieties of yam "*Dente*" and "*Pona*" 240 each was marked, weighed and loaded into both the circular and rectangular barns. Each variety was put into four groups with four replications. Each replication was made up of 15 tubers making 480 tubers of each yam variety in both barns totaling 960 yam tubers in both storage structures. However, each barn was fitted with a data logger to record the internal temperature and relative humidity. One of the data loggers was installed outside to measure the ambient temperature and relative humidity.

### 3.4 Sourcing of yam tubers

The yam tubers used for this study were white yam (*Dioscorea rotundata* Poir) which is the most commonly cultivated specie among the farmers in the area of study. All the yam tubers used in the study were purchased and obtained from one farm in the growing area.

### 3.5 Field Survey

A number of hundred structured questionnaires were administered on yam producers using simple random sampling procedure and used to conduct a survey to ascertain the methods that are adopted by farmers in the Ejura - Atebubu Districts for the storage of yams, yam variety cultivated most by farmers, the best among several commonly used yam storage methods and farmers‟ knowledge on post-harvest losses in yams during storage.

### 3.6.0 ENVIRONMENTAL PARAMETERS

#### 3.6.1 Temperature and Relative humidity inside the Barns

Readings were recorded using a digital thermo-hygrometer logger TV 4500 Tinytag Explorer View 2, Version 4.8 by Gemini data loggers (UK) Ltd.

### 3.6.2 Temperature and Relative humidity outside the Barns

Readings were recorded using a digital thermo-hygrometer logger TV 4500 Tinytag Explorer View 2, Version 4.8 by Gemini data loggers (UK) Ltd.

## 3.7.0 PHYSIOLOGICAL PARAMETERS

### 3.7.1 Percentage Weight Loss

The tubers were weighed before and on monthly interval during the storage period. The percent weight reduction for each month was calculated on account of the initial tuber weight utilizing the formula:

$$Wl_n = \frac{(Wo-Wn)}{Wo} \times 100\%$$ ……………………………………..…..…….Equation 1

**$WL_n$**= present magnitude of percent weight loss; **$W_0$**= original fresh weight of tuber (kg); **$W_n$** = present weight of tuber (kg) (Ezeike, 1984).

### 3.7.2. Percentage Sprouting

The rate of sprouting was assessed by de–sprouting the tubers manually. This was done on monthly interval and the sprouted tubers counted. The average monthly sprouting was therefore computed and the percentage calculated using the formula by Opara (1999):

$$\text{Sprouting index} = \frac{\text{Number of sprouted tubers}}{\text{Total number of Tubers}} \times 100$$ ……………................. Equation 2

### 3.7.3 Percentage Tuber rot

Number of rotten tubers was recorded during weighing of the tubers by visual examination after cutting samples both transverse and longitudinal. The percentages were calculated using the formula by Opara (1999):

$$\text{Percentage Rots} = \frac{\text{Number of Rotten tubers}}{\text{Total number of Tubers}} \times 100$$ ……………………..…Equation 3

### 3.8 Percentage of Damaged tubers due to insects and rodents

Percentage of tubers damaged by rodents and insects over the period was determined through visual examination. It is calculated using the formula;

$$\text{Percentage Rodent damage} = \frac{\text{Number of damaged tubers}}{\text{Total number of Tubers}} \times 100$$ ………......Equation 4

### 3.9 Experimental Design

The experimental design used was a 2×2 Factorial laid out in Completely Randomized Design (CRD) with four replications.

### 3.10 Data Analysis

The questionnaires were analyzed using Statistical Package for Social Sciences (SPSS) software (version 16.0). The count data collected on the performance of the yams were transformed using square root transformation $\sqrt{1 + x}$ where „x" is the counted data.

Statistical significance of the transformed data was established by Analysis of Variance (ANOVA) using GenStat Statistical software version 11.1, Copyright 2008, VSN International Ltd. at ($P \leq 0.05$) LSD and also by Microsoft Excel and the results were interpreted and presented using descriptive and inferential statistics .

CHAPTER FOUR

# 4.0 RESULTS AND DISCUSSION

## 4.1.0 Field Survey

### 4.1.2 Background Information of Respondents

The survey outcome confirmed that males dominated the cultivation of yam with 63% as opposed to 37% of the women (Figure 10.0). This could be due to the socio-cultural norms of the people which relegate women to the kitchen and the men as bread-winners.

The ages of interviewees range from 19 years to 60 years and above. Majority of the interviewees thus 34% have their ages hovering between 19 to 29 years, with 27% also ranging between 30-39 years as the second year group, 15% are aged (60 years and beyond), 12% in the age range of 40-49 years as well as 50-59 years. This indicates that (61%) of the farmers are within the age range of 19–39 years which represents the youthful age group with the strength and vigour to venture into sustainable production of yam (Figure 11.0) .

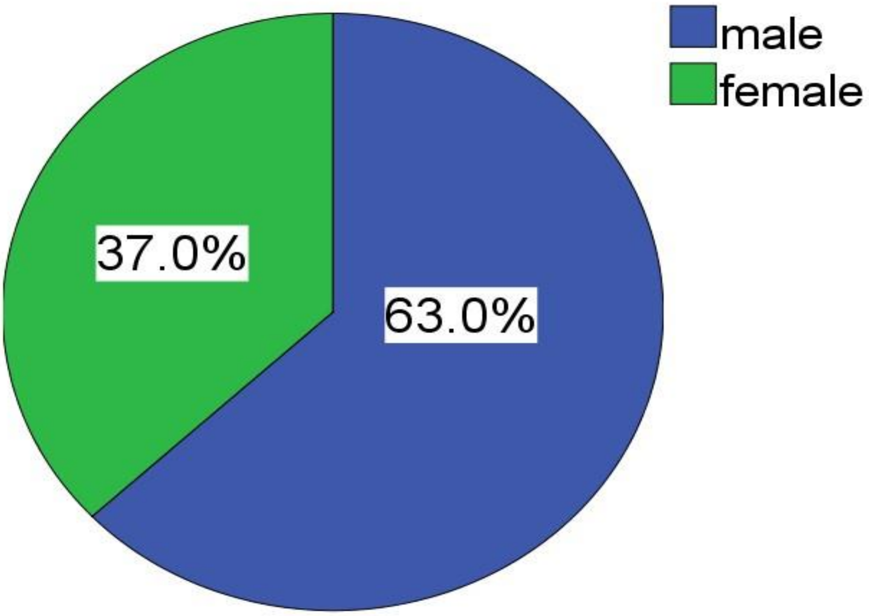



**Figure 10 Gender description of respondents**

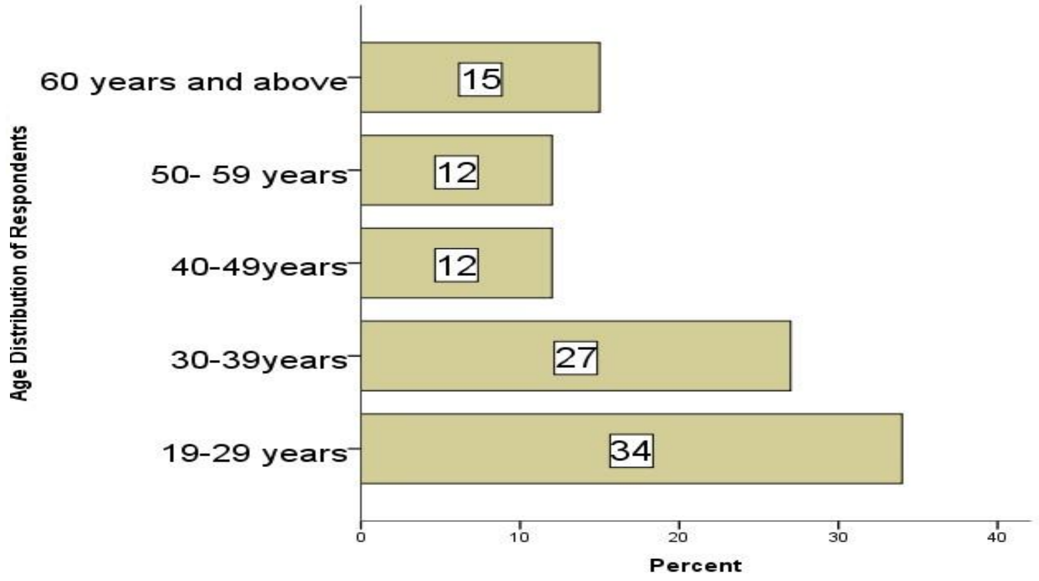



**Figure 11 Age distribution of respondents**

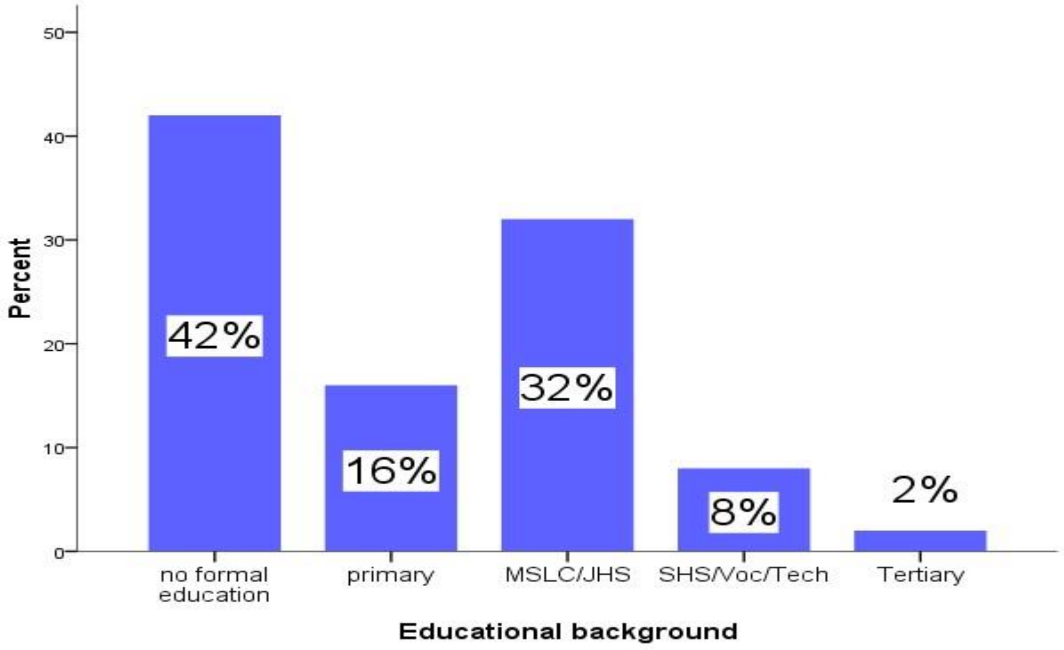



**Figure 12 Educational background of respondents**

The survey outcome gave the following distribution on the level of education of respondents: 42% had no formal education, 16% had basic education, and 32% had education up to the JHS, 8% up to SHS level and only 2% had university or higher education (Figure 12.0). From this outcome, it can be inferred that the youth have developed a lot of interest in farming and majority of them might have taken into the farming business since they could not pursue further education after the Junior High School (JHS). Only a few (2%) of the respondents had reached university or higher level of education.

### 4.1.3 Yam Variety and Level of Production

### 4.1.4 Yam Variety

The respondents interviewed were producers of the two yam varieties *Pona* and *Dente*. After the interview, it came out that 48% of the respondents produce *Pona* while majority of them representing 52% cultivate *Dente* as shown in Figure 13.0

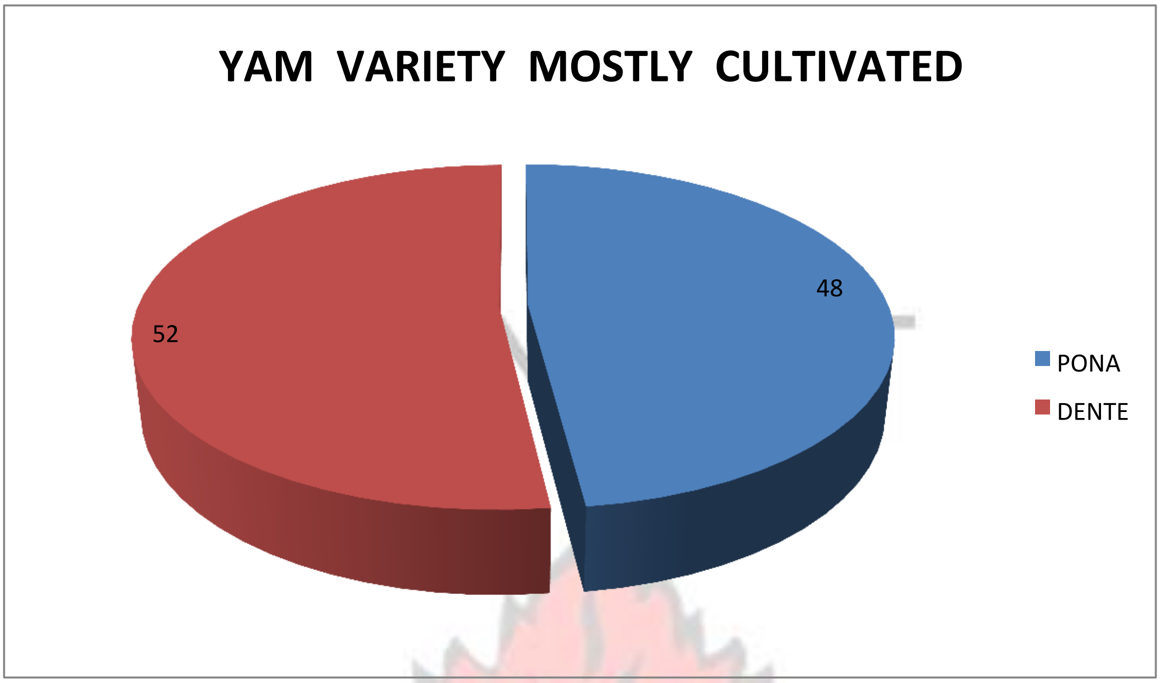



**Figure 13 Variety produced more among the two varieties**

### 4.1.5 Storage Losses

Thirty-five percent (35%) of the farmers reported that, the storage losses incurred ranged between 1-10%, 29% suffered between 11-20% losses while the rest (36%) of the producers suffer storage losses above 20% (Figure 14.0). The respondents ascribed the losses during storage of their harvested produce to a few predisposing causes particularly germination, decomposition, bruises, invading animals and loss of weight which majority (40.82%) of them acknowledged rot as their fundamental difficulty (Figure 15.0).

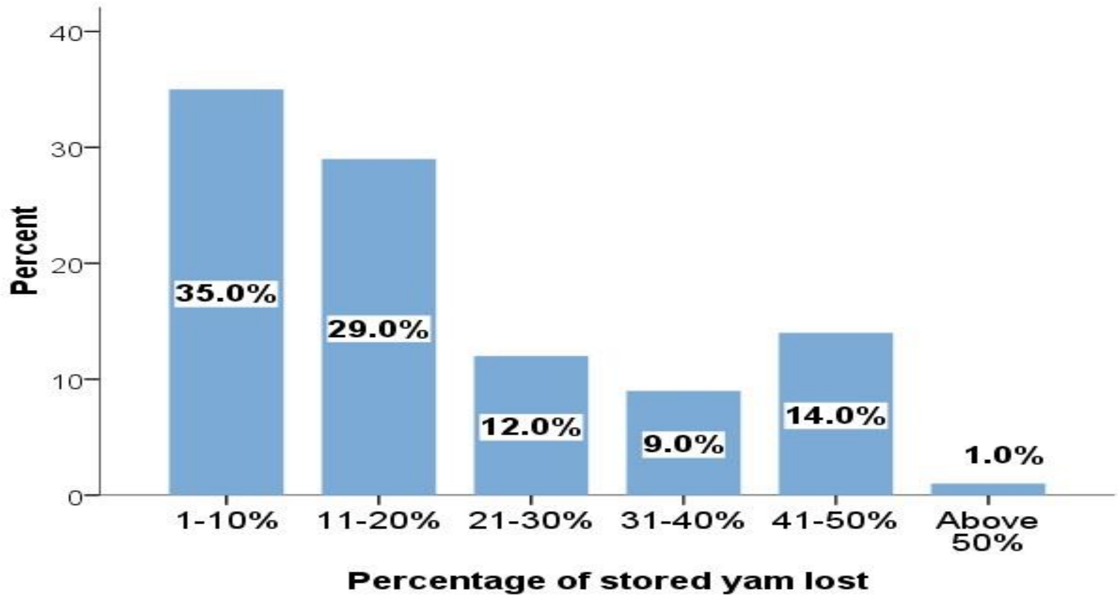



**Figure 14 Percentage of stored yam lost**

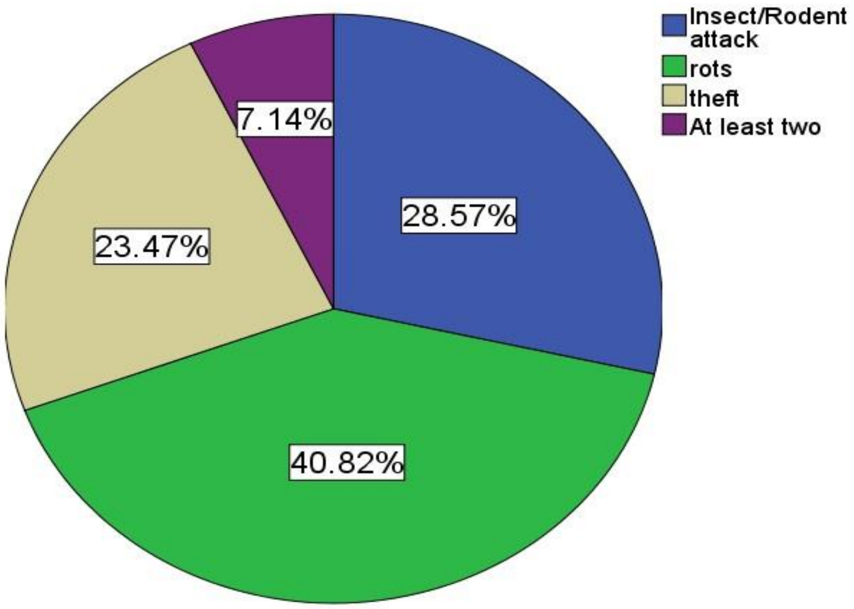


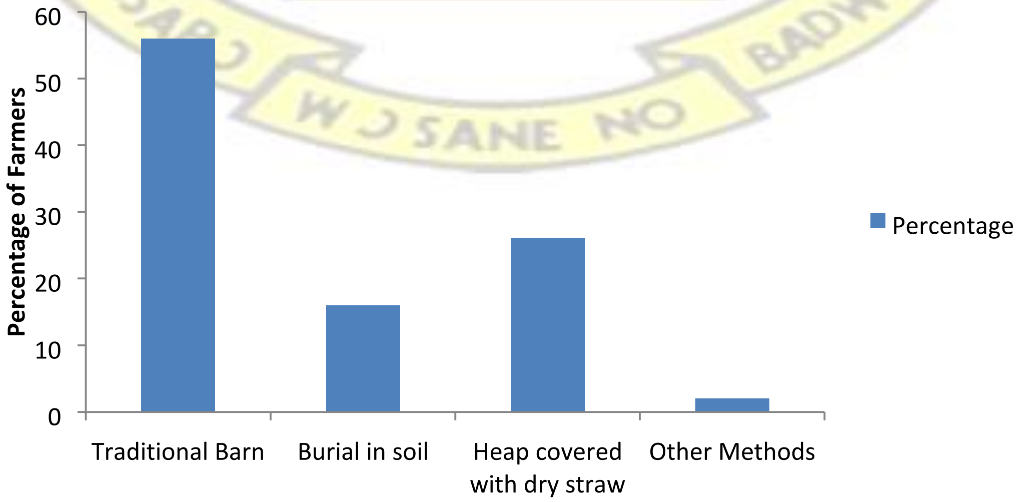

**Figure 15 Storage losses that pose major concern**

### 4.1.6 The best among several commonly used yam storage methods

**Table 1 Storage method and construction material availability**

| Storage Method | Whether materials used for storage structure construction are readily available | | Total |
|---|---|---|---|
| | Yes | No | |
| Barn storage | 41 | 15 | 56 |
| Burial in soil | 15 | 1 | 16 |
| Heaping on the floor covered with dry straw | 25 | 1 | 26 |
| Other methods | 1 | 1 | 2 |
| **Total** | **82** | **18** | **100** |

(*Dzukey, 2015*)



Storage methods

**Figure 16 Percentage of various storage methods used by farmers**

Information gathered from the figure 16 indicates that the traditional yam barn is most patronized by majority of the farmers. This seem to suggest that any introduction of a storage system must be one that is similar in design and material for construction to the existing traditional barn.

**Table 2 Respondent using barn storage with construction material readily available and their estimation on average cost of a well enclosed structure**

| Count | Average cost of a fully enclosed 500 tubers capacity yam storage structure | Total |
|---|---|---|

**Respondents using barn** Less than 500-1000 More than **storage with storage**

**structure** 500 cedis cedis 1000

| **material available** | | | cedis | |
|---|---|---|---|---|
| | 23 | 17 | 1 | 41 |
| Total | **23** | **17** | **1** | **41** |

Majority (56) of farmers use traditional barn storage; out of which 41 indicated that storage structure materials were readily available in their locality (Table 2.0). Twenty three (23) out of the 41 respondents using the traditional barn also indicated that construction materials were readily available in their locality and stated less or moderate cost as a factor for a well enclosed structure. This outcome indicates that material availability will result in low or moderate cost of storage (Table 2.0) hence the high patronage of a particular storage method (Figure 16.0).

**Table 3 Percentage tuber weight loss in both Circular and Rectangular barns versus months of storage**

| | | **% Tuber Weight loss/ Months of Storage** | | | |
|---|---|---|---|---|---|
| **Barn Type** | Variety | March | April | May | June |
| **Circular** | *Pona* | 9.5 | 50.6 | 51.7 | 58.5 |
| | *Dente* | 7.5 | 37.9 | 3.8 | -1.7 |
| **Rectangular** | *Pona* | 10.8 | 28.7 | 7.2 | 9.3 |

| | | | | |
|---|---|---|---|---|
| *Dente* | 6.8 | 35.5 | 44.7 | 51.3 |

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**4.2 Weight loss**

**Table 4 Effect of Barn type on tuber weight of yam varieties stored.**

| **Treatment** | **Tuber Weight (kg)** | | | |
|---|---|---|---|---|
| **Storage Duration (Months)** | March | April | May | June (2015) |
| **<u>Variety</u>** | | | | |

| | | | | |
|---|---|---|---|---|
| Pona | $3.40_{NS}$ | $6.44_{NS}$ | 3.03 | $4.30_{NS}$ |
| Dente | 2.94 | 6.29 | $3.47_{NS}$ | 3.61 |
| LSD (5%) | 0.63 | 1.11 | 0.96 | 1.71 |
| **Barn type** | | | | |
| Circular | 3.25 | 6.22 | $3.29_{NS}$ | 3.75 |
| Rectangular | $3.09_{NS}$ | $6.51_{NS}$ | 3.26 | $4.16_{NS}$ |
| LSD (5%) | 0.63 | 1.11 | 0.96 | 1.71 |
| CV (%) | 2.7 | 4.00 | 20.8 | 16.5 |

Key: NS = Not significant; * Significant

Throughout the storage duration, type of yam variety did not have any significant (P > 0.05) effect on tuber weight even though "*Pona*" showed marked reduction in weight (Table 4.0). Also, barn type did not register any significant effect on the cumulative weight loss in both yam varieties. The tubers in the rectangular barn (*Dente and Pona*: 45.8%; 55.8%) had their weights significantly reduced particularly at the tail-end of the storage period than in the circular barn (*Dente* and *Pona*: 45.7%; 53.8%) (Appendix 2.0 and 3.0). This difference could be attributed to the nature of ventilation in the rectangular structure since the better the rate of air relocating over fresh produce the more rapid is water loss through transpiration (FAO, 1998). This reduction in weight of yam tubers is ordinarily due to excessive respiration (mostly because of the breakdown of stored carbohydrate) of products under storage happening consequently of continual heat and accordingly result in loses after harvest.

It is rightly correlated with lack of water or moisture inside a produce due to transpiration. The release of energy, moisture loss from plant surfaces and germination are the main causes of reduction in weight. These processes really have an impact on the appearance and cause tubers to shrink. Reduction in weight moreover influences yam tuber acceptability after storage (Ikediobi & Oti, 1983).

### 4.3 Rotting Tubers

**Table 5 Effect of Barn type on tuber rots of yam varieties stored.**

| **Treatment** | **Tuber Rots** | | | |
|---|---|---|---|---|
| **Storage Duration (Months)** | March | April | May | June (2015) |
| **Variety** | | | | |
| Pona | 5.24* | 1.39* | 1.10$_{NS}$ | 3.12* |
| Dente | 1.71 | 1.00 | 1.00 | 1.00 |
| LSD (5%) | 3.07 | 0.22 | 0.17 | 1. 23 |
| **Barn type** | | | | |
| Circular | 3.12 | 1.19 | 1.05 | 2.02 |
| Rectangular | 3.83 | 1.19$_{NS}$ | 1.05$_{NS}$ | 2.10$_{NS}$ |
| LSD (5%) | 3.07 | 0.22 | 0.17 | 1.23 |
| CV (%) | 20.4 | 10.4 | 5.6 | 44.2 |

Key: NS = Not significant; * Significant

For the months of March, April and June, 2015; „*Pona*" recorded significant ($P < 0.05$) increase in the number of rotten yam tubers in both the circular and rectangular barns respectively. Thus, (*Pona*: 5.8%; 5.4%) as indicated in Appendix 8.0 and 9.0. This peculiar trait of *Pona* yam variety was also reported by Yusuf (2013).

However, the „*Dente*‟ variety which was also stored under the same condition did not register any significant (P > 0.05) increase in the number of rotten tubers (*Dente*: 0.00%; 0.42%) (Appendix 8 and 9). The variety „*Pona*" preferred for its taste is one of the more perishable varieties. Losses can account for as much as 50% of production.

The high percentage of rots in „*Pona*" and a marginal increase in rots in „*Dente*" could be attributed to varietal difference and genetic variability. It could also be due to the presence of some phytochemicals in the yam tubers (Burkil, 1985). This explains why a greater number of the farmers (respondents) prefer growing *Dente* to *Pona (*Figure 13.0).

**Figure 17 Longitudinal and transverse cuts of '*Dente*' yam (left) and transverse cut of '*Pona*' yam (right) in identification of rots.**

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**4.4 Sprouting**

**Table 6 Effect of Barn type on tuber sprouts of yam varieties stored**.

| Treatment | Tuber Sprouts |
|---|---|

| Storage Duration (Months) | March | April | May | June (2015) |
|---|---|---|---|---|
| **Variety** | | | | |
| Pona | 6.09 | 6.13 | 7.02 | 6.78 |
| Dente | $7.03_{NS}$ | $7.66_{NS}$ | $7.27_{NS}$ | 7.68* |
| LSD (5%) | 0.81 | 2.20 | 0.86 | 0.62 |
| **Barn type** | | | | |
| Circular | 6.07 | 6.68 | $7.04_{NS}$ | $7.56_{NS}$ |
| Rectangular | $7.04_{NS}$ | $7.66_{NS}$ | 7.25 | 6.90 |
| LSD (5%) | 0.81 | 2.20 | 0.86 | 0.62 |
| CV (%) | 8.3 | 13.5 | 3.7 | 8.7 |

Key: NS – Not significant; * Significant

The results shown table 6.0 indicate that there was no significant increase (P >0.05) in the number of sprouts for the first three months of storage but the fourth month (June) recorded significant increase (P < 0.05) in the number of sprouts for „*Dente*‟ variety (95% and 80%) compared to „*Pona*‟ (62.5% and 75.5%) in both Circular and Rectangular barns respectively (Table 7.0). Barn type did not show any significant effect (P > 0.05) on sprouting of both yam varieties.

However, „*Dente*‟ variety exhibited a progressive increase in the number of sprouts over the period in both barns than the „*Pona*‟ which was stored under the same condition. This marked increase in the number of sprouts and sprouting vigour shown by the „*Dente*‟ variety

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(Figure 18.0) could be attributed to intra-specie and genetic variability or possibly from the plant‟s own growth hormones.

**Figure 18 ‘*Dente*’ yam variety (left) showing intense sprouting compared to ‘Pona’ variety (right).**

**Table 7 Percentage sprouts in both Circular and Rectangular barns versus months of storage**

| | | % Sprouts/ Months of Storage (2015) | | | |
|---|---|---|---|---|---|
| **Barn Type** | **Variety** | **March** | **April** | **May** | **June** |
| **Circular** | ***Pona*** | **28.3** | **55.0** | **70.0** | **75.5** |
| | ***Dente*** | **45.0** | **87.5** | **77.5** | **95.0** |
| **Rectangular** | ***Pona*** | **45.0** | **55.0** | **72.5** | **62.5** |
| | ***Dente*** | **53.3** | **87.5** | **80.0** | **80.0** |

### 4.5 Pest Damage

**Table 8 Effect of Barn type on pest damage of yam varieties stored.**

| **Treatment** | **Pest Damage** |
|---|---|

| Storage Duration (Months) | March | April | May | June (2015) |
|---|---|---|---|---|
| **Variety** | | | | |
| Pona | 1.00 | 1.00 | 1.09$_{NS}$ | 2.86* |
| Dente | 1.00$_{NS}$ | 1.00$_{NS}$ | 1.05 | 1.22 |
| LSD (5%) | 0.00 | 0.00 | 0.25 | 1.31 |
| **Barn type** | | | | |
| Circular | 1.00 | 1.00 | 1.00$_{NS}$ | 2.38 $_{NS}$ |
| Rectangular | 1.00$_{NS}$ | 1.00 $_{NS}$ | 1.14 | 1.71 |
| LSD (5%) | 0.00 | 0.00 | 0.25 | 1.31 |
| CV (%) | 0.00 | 0.00 | 8.3 | 34.5 |

Key: NS = Not significant; * Significant

During the first three months of storage (March to May, 2015) both yam varieties did not record any significant (P > 0.05) damage by pest mainly insects and rodents. However, „*Pona*" recorded significant (P < 0.05) damage by rodents and insects during the fourth month (June, 2015) (*Pona*: 2.86; *Dente*: 1. 22) (Table 8.0). This could be ascribed to tree branches touching the roof of the storage structure which needed to be pruned periodically and improper fixing of rodent guards which might have served as access route for rodents into the structure. The increase in the destruction of *Pona* could also be attributed to the dietary preference of the rodents.

Barn type did not register any significant effect on Pest damage. However, the total prevalence of rodent damage in the Circular barn surpasses that recorded in the rectangular barn (Circular barn: 7.6%; Rectangular: 1.7%) (Appendix 12.0).

**Figure 19 '*Pona*' yam variety seriously damaged by rodents exposing it to rot pathogens (left)**

### 4.6.0 TEMPERATURE AND RELATIVE HUMIDITY

#### 4.6.1 Temperature and Relative Humidity in and outside the Circular barn

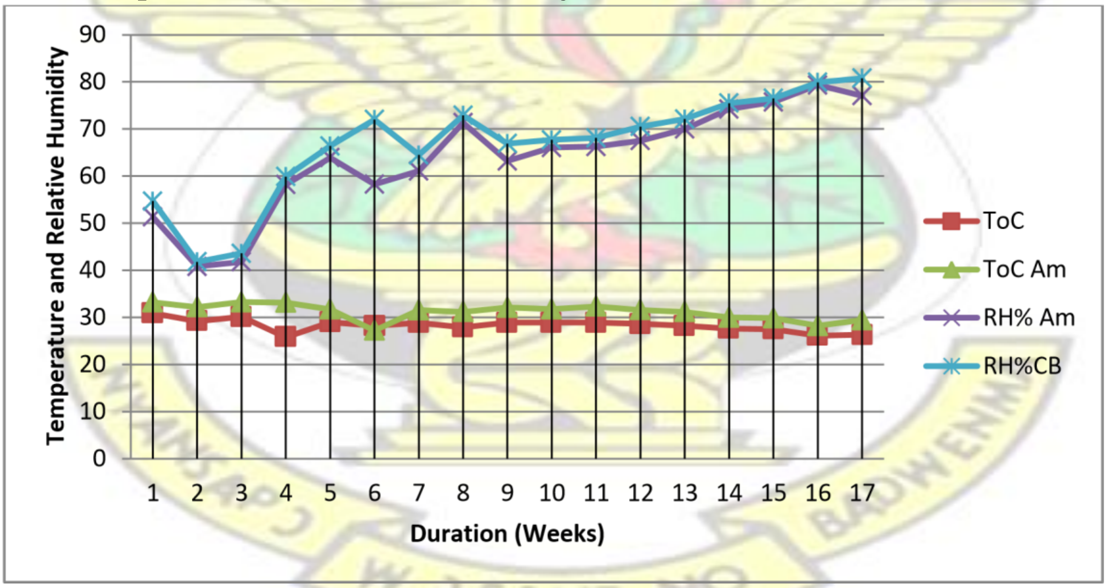


**Figure 20 Weekly Average Temperatures (T°C) and Relative Humidity (RH %) inside and outside the Circular Barn.**

Figure 20.0 illustrates the weekly average temperature and relative humidity readings inside and outside the circular barn recorded over the duration of the storage (17 weeks). It was observed that there were peak relative humidity readings during the 6$^{th}$ and 8$^{th}$ weeks (ending of March, 2015) and (Mid April, 2015) of storage and a decline in the 9$^{th}$ – 11$^{th}$ week (April, 2015 to May, 2015). Relative humidity ranged between 41.8% - 80.8% showing an average value of 66.7%. However, there was also a steady increase in relative humidity from 11$^{th}$ week to the 17$^{th}$ week (May, 2015 to June, 2015).

The ambient relative humidity gave a range of 40.8% - 79.3% with an average value of 63.9%. Temperature on the other hand saw an initial high and a gradual decline through to the 17$^{th}$ week (June, 2015). It varied between 25.8 $^{o}$C to 30.9 $^{o}$C with an average of 28.3$^{o}$C. Generally, the ambient temperature was relatively high ranging from 27.2$^{o}$C to 33.2$^{o}$C averaging 31.2$^{o}$C. This could have a corresponding increase in the rate of sprouting in the barns for example „*Dente*" variety 77.5%, 87.5%, 95% and 53.3%, 87.5%, 80% in both Circular and rectangular barns respectively (Table 7.0). In addition, the gradual increase in the relative humidity to the latter week of storage as shown in (Figure 20.0) also gave a corresponding increase in rate of sprouting 95% and 80% for „*Dente*" in both Circular and rectangular barns respectively (Table 7.0).

It could also be deduced from Figure 20.0 that all the recorded temperature readings both internal and ambient exceeded the standard room temperature of 25$^{o}$C therefore the combined effect of high temperature and relative humidity served as a catalyst for the high rate of respiration of tubers leading to the high weight loss of stored yam tubers. This phenomenon could be attributed to the convective movement of air current through the structure based on the nature of its design.

**4.6.2 Temperature (T$^{o}$C) and Relative Humidity (RH %) inside and outside the Rectangular Barn**

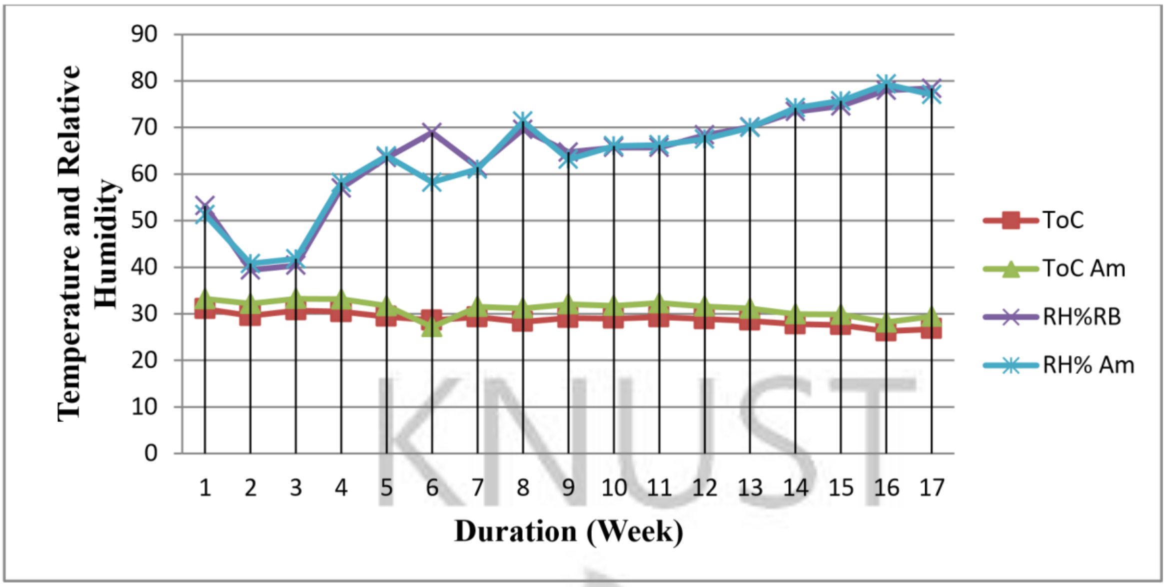


**Figure 21 Temperature (T°C) and weekly average Relative Humidity (RH %) inside and outside the Rectangular Barn**

The temperature (T°C) and relative humidity (Rh %) condition within and outside the rectangular barn over the entire duration of storage has been illustrated in Figure 21.0. The 8th (April, 2015) and 14th (May, 2015) to 17th (June, 2015) weeks recorded relatively higher humidity readings within the rectangular barn than the ambient. There was a sharp decline in both internal and ambient relative humidity for the 2nd and 3rd weeks (May, 2015) and showed a progressive increase from the 11th to 17th week (May to June, 2015). Relative humidity within the rectangular barn varied between 39.4% - 78.4% with an average of 64.3%. That of the ambient ranged between 40.8% - 79.3% with an average value of 63.9%. Generally, there was a relatively steady temperature reading recorded except week 6 which registered a sharp decline. The internal temperature varied from 26.3°C to 31°C with an average value of 28.9 °C whilst the ambient ranged from 27.2 °C to 33.2 °C and averaged 31.2 °C. This condition of the air both within and outside the rectangular barn as presented above might have contributed to the high rate of sprouting in *Dente* especially during the 2nd Month (April) (87.5%) and in *Pona* during the 3rd Month (May, 2015) (72.5%) (Table 7.0) as depicted in (Figure 21.0) during the 6th and 8th weeks (March and April, 2015).

**4.6.3 Correlation between Relative Humidity and Sprouting in both Circular and Rectangular Barns.**

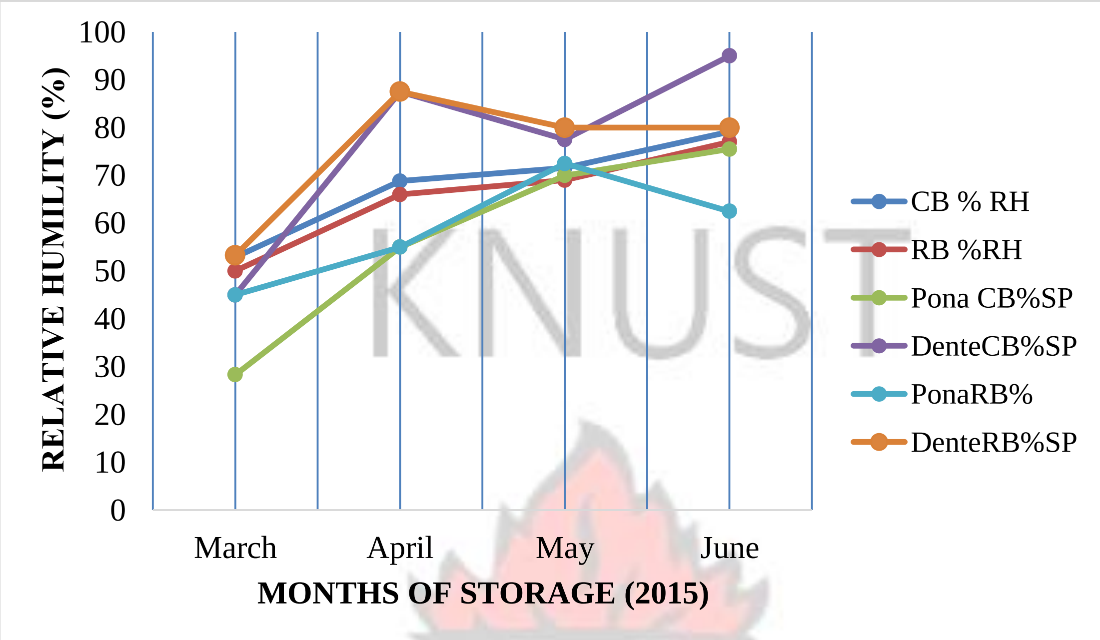


**Figure 22 Correlation between monthly average Relative Humidity and Sprouting of *Dente* and *Pona* varieties in both Circular and Rectangular Barns.**

Figure 22.0 shows how the prevailing monthly average relative humidity correlates with the sprouting index of *Dente* and *Pona* yam varieties in both the Circular and Rectangular barns. Sprouting in both the Circular and Rectangular barns increased steadily (*Pona*: 75.5%, 62.5; *Dente*: 95.5%, 80%) with increasing internal relative humidity of (79.1% and 77%) for the month of June, 2015 (Appendix, 13.0). This intensified throughout the month of June, 2015 with the on-set of the rains when the percentage of moisture in the atmosphere increases. Consistent with Wickham (1984), high humidity for instance in the beginning of the wet season, promotes germination. At the same time low humidity on the other hand, extends the dormancy period in stored yam tubers.

**4.6.4 Correlation between average monthly Temperatures and Sprouting in both Circular and Rectangular Barns.**

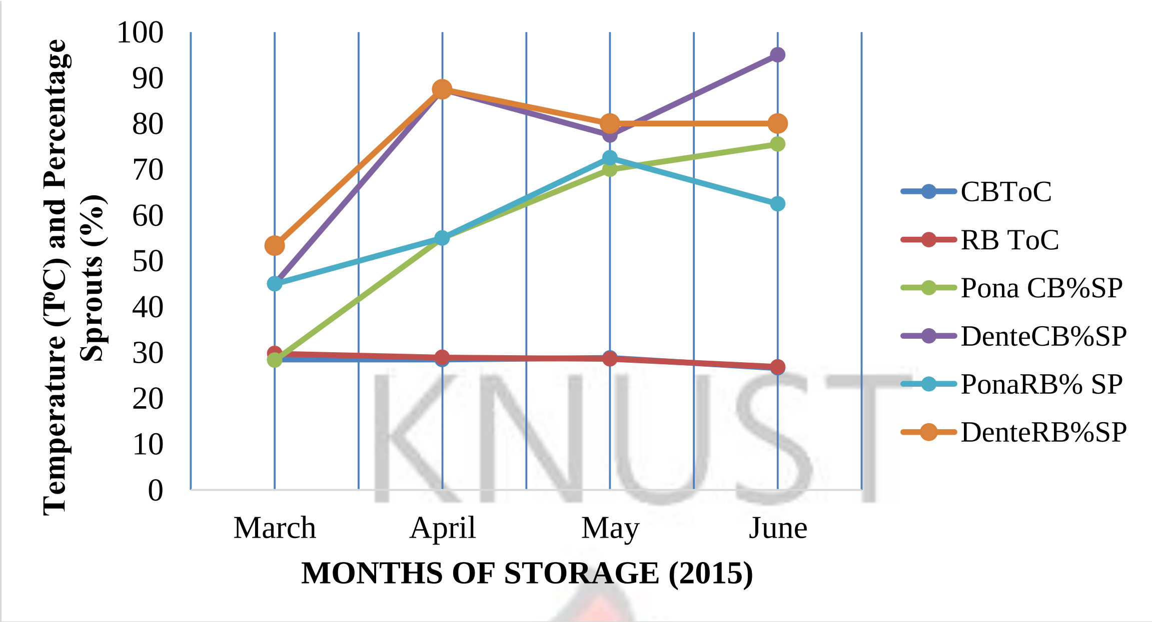


**Figure 23 Correlation between average monthly Temperatures and Sprouting of Dente and Pona varieties stored in both Circular and Rectangular Barns.**

Figure 23.0 gives an illustration of how the yam performed under storage thus how the average monthly temperatures correlates with sprouting of both *Dente* and *Pona* varieties in the Circular and Rectangular Barns. Initial average monthly temperatures were relatively high (28.5 °C and 29.8°C) [Appendix 13.0] for both Circular and Rectangular barns respectively during the month of March, 2015. This however declined steadily to (26.6 °C and 26.9°C) [Appendix 13.0] for both Circular and Rectangular barns respectively during the month of June, 2015 when the wet season is intense.

However, these temperature recordings are much higher than the standard room temperature of 25°C and led to a corresponding increase in the percentage sprouts (*Pona*: 75.5%; 62.5 and *Dente*: 95%; 80%) [Appendix 13.0] for both circular and Rectangular barns respectively in the month of June, 2015. As stated by Passam (1982), a decline in temperature by just a few degrees Centigrade has the capacity to prolong dormancy in stored farm produce. On the contrary, an upward thrust in temperature reduces dormancy.

## CHAPTER FIVE

# 5.0 SUMMARY, CONCLUSION AND RECOMMENDATION

## 5.1.0 SUMMARY AND CONCLUSION

Post-harvest losses in yams during storage continue to be a great disincentive to the farming business. Every season, quite a sizeable and significant number of yam tubers undergo deterioration in storage due to sprouting, weight loss, rot and pest damage. It therefore becomes imperative to find a more suitable and workable means of improving yam storage using relatively cheaper and available materials in construction of storage structures to keep the surplus harvest and make the crop available all 12 months round.

The survey revealed that, three traditional storage methods were most prevalent in the yam growing areas; traditional barn, burial in the soil and heap on floor covered with straw. The traditional barn was the best and has the ability to store produce for a relatively longer period and hence are used by the majority (56%) of the farmers. The survey also established that farmers already have some knowledge on post-harvest losses during storage. They attributed the causes of storage losses to several factors including decay, bruises, animal invasion, reduction in weight and sprouting. Majority (40.82%) of the respondents indicated rot as their major concern. This work therefore assessed and tested the post-harvest performance of two newly designed and constructed yam barns on the storability of two yam varieties; "*Pona*" and "*Dente*".

The 240 tubers of each variety observed for 120 days recorded the following results in both the circular and rectangular barns respectively: weight loss (Pona: 21%, 28.6%; Dente: 30.8%; 32.2%); tuber sprouts (Pona: 40.4%, 42.9%; Dente: 54.6%; 54.6%); tuber rots (Pona: 5.8%, 5.4%; Dente: 0%; 0.42%); rodent and insect damage (Pona: 6.9%, 1.7%; Dente: 0.63%; no rot).

Temperature and relative humidity in and outside both barns were monitored over the storage duration. Results showed that, the weekly average temperature and relative humidity in both circular and rectangular barns were (28.30°C and 66.7%) and (28.9°C and 64.3%) respectively while the ambient recorded 31.2°C and 63.9 %, respectively.

Based on the results obtained, it can be concluded that under the prevailing environmental condition, the improved circular and rectangular barns which are affordable and when pitched under shade can significantly reduce storage losses at a temperature range of 25 $^{o}$C to 28 $^{o}$C and relative humidity range of 60% to 64%.

Also, either the circular or rectangular barn could be used for yam storage as they can significantly reduce losses due to rots, weight loss, tuber sprouts and pest damage.

**5.1.1.0 KEY FINDINGS**

„ *Pona*‟ variety was found to be more susceptible to rots in both barns than „*Dente"* which proved to be more tolerant under the same condition.

Barn type and variety did not record any significant effect on percentage weight loss.

There was significant increase in percentage tuber sprouts for „*Dente*‟ variety over *Pona* during the month of June, 2015.

Barn type did not show any significant effect on percentage sprouts.

„*Pona*‟ variety was found to be more susceptible to pest damage whilst *Dente* was more tolerant.

Barn type did not show any significant effect on percentage pest damage.

### 5.2 RECOMMENDATION

After the storage experiment, it is recommended that several trials be carried out in the two structures (Barns) to determine the optimal conditions for storage of specific popular yam varieties. It is recommended for farmers that storage of *Pona* and *Dente* as ware yams in both the Circular and rectangular barns are limited to the first four months after harvest. Also, both barns can be used to assess the stored yams for processing and storage qualities at different stages of storage and maturity. Though *Dente* recorded marginal percentages in terms of rots, rodents and weight loss, its high rate of sprouting is undesirable. In view of this, a special structure can be designed for its storage. In addition, the method of stacking the yams in the barns can be researched into to arrive at a suitable way of stacking yams.

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# APPENDICES

## APPENDIX 1.0 QUESTIONNAIRE FOR DATA COLLECTION A STUDY ON YAM STORAGE METHODS

**Preamble:**

The main purpose of this study is to ascertain the methods that are adopted by farmers in the Ejura - Atebubu Districts for the storage of yams, yam varieties cultivated mostly by farmers, the best among several commonly used yam storage methods and farmers‟ knowledge on post-harvest losses in yams during storage. This questionnaire is designed to assist the researcher to acquire first- hand information as regards to the purposes stated above. Please, kindly take some time to respond to these items candidly as possible. Your answers will enable the researcher find some possible solutions to the problems associated post-harvest storage of yam in the two yam growing districts. All answers given would be treated with the needed confidentiality.

SECTION A: BACKGROUND INFORMATION OF RESPONDENTS

1. Age…………………………………………………………………………………

2. Sex of Respondent a. Male [ ] b. Female [ ]

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[ ] e. Tertiary [ ]

SECTION B: FARMING AND PRODUCTION PRACTICES OF FARMERS

5. Which type of farm do you have? a. Subsistence farming [ ] b. Commercial farming [ ]

6. Do you cultivate other crop(s) in addition to yam? a. Yes [ ] b. No [ ]

7. If yes, specify………………………………………………………………..….

8. What varieties of yam do you cultivate? *a. Pona* [ ] b. Water yam [ ] c. *Dente*[ ] d. other(s) [ ] specify………………………..……………………...................................

9. How do you determine the stage of maturity of the tuber?

a. Visual observation [ ] b. Calendar date [ ] c. Both [ ]

10. How many yams do you harvest per season? a. Less than 100[ ] b. 100-500[ ] c. 6011000 d. More than 1000[ ]

11. What do you do after harvest? a. Sell [ ] b Store [ ] c. Both [ ]

12. What percentage of yam is sold? a. Less than 10% [ ] b. 10-20% [ ] c. 21-30% [ ] d. 3140% [ ] e. More than 40%[ ]

13. Why do you sell your yam after harvest? a. income [ ] b. unreliable storage method[ ] c. Other [ ]
(specify).........................................................................................................................

14. Why do you store your yam after harvest? a. Higher prices b. No immediate transportation c. other [
](specify)........................................................................................................................

15. Do you apply any treatment to the yam before storing? a. Yes [ ] b. No [ ]

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

17. Why do you apply the treatment? ………………………………………………

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

19. Why do you use the method indicated above? a. Long storage [ ] b. Short storage [ ] c. Less fund [ ] d. Both „b‟ and „c‟ [ ] e. other (specify).........................................................................zzz......................................

20. What other way do you store your yam?..........................................................................

21. Under very good storage conditions how long are the tubers expected to maintain the best eating and marketing qualities? a. 4-6 months b. 3-1 months c. Less than a month. d. other(specify).........................................................................................

22. How long have you been able to maintain the best of eating and marketing qualities using the method(s) indicated above a. 4-6 months [ ] b. 3-1 months [ ] c. Less than 1monts[ ]. d. other(specify)………………………………………………………………………………

23. At what time during the storage period the highest loss occurs?
a. Within a month [ ] b. 2-3 months [ ] c. After 4 months [ ]

24. How much of your stored yam are lost? a. 1-10% [] b. 11-20% [ ] c. 21-30% [ ] d. 3140%[ ] e. 41-50 %[ ] f. Above 50%[ ]

25. What causes the losses? a. Injuries [ ] b. Pests [ ] c. Decay [ ] d. Sprouting [ ] e. All [ ] other(s) [ ] specify ………..........................................................................

26. Which of the storage losses is of a major concern? a. Insect attack [ ] b. rots [ ] c. theft [ ] e. bruises [ ] others (specify)…………..............................................................

27. In your estimation, what percentage of yam sprouts? a. up to 10 % [ ] b. 11-20% [ ] c. more than 20% d. None [ ]

28. In your estimation what percentage of yam rots? a. up to 10 %[ ] b. 11-20% [ ] c. more than 20%[ ] d. None [ ]

29. In your estimation what percentage of yam are attacked by Insect/rodents? a. up to 10 %[ ] b.11-20%[ ] c. more than 20%[ ] d. None [ ]

30. In your estimation what percentage of yam are lost through theft? a. up to 10 %[ ] b. 11-20%[ ] c. more than 20%[ ] d. None [ ]

31. What do you do with such bruised tubers? a. Sell immediately [ ] b. eat at home [ ] c. both [ ] d. other (specify)……………………… ………………………………..

32. Which of these two varieties rots quickly? a. *Pona* [ ] b.*Dente*[ ]

33. Is the material used for the storage structures readily available at your locality? a. Yes [ ] b. No [ ]

34. What is the average costs a well enclosed structure with five (5) hundred tuber capacity storage? a. Less than 500 Cedis [ ] b. 500-1000 Cedis [ ] c. More than 1000 Cedis [ ]

35. How do you control injuries? a. None [ ] b. Control [ ] (specify)……………..…………………………………..……………………………

36. How do you control Pest? a. None [ ] b. Control [ ](specify)…………………...…………………………………...………………………

37. How do you control Sprouting a. None [ ] b. Control [ ] (specify)……..…………………………..……………………………………………

38. What other constraints affect your yam production business that may have resulted in storage losses? ……………………….……………..............................

**APPENDIX 2.0 Anova Tables on Effect of Variety and Barn type on tuber weight of yam stored under different conditions.**

**Variate: March %TW**

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| REP stratum | 3 | 0.0909 | 0.0303 | 0.10 | |
| REP.*Units* stratum | | | | | |
| BN | 1 | 0.0977 | 0.0977 | 0.31 | 0.590 |
| VAR | 1 | 0.8327 | 0.8327 | 2.66 | 0.138 |
| BN.VAR | 1 | 0.0371 | 0.0371 | 0.12 | 0.739 |
| Residual | 9 | 2.8201 | 0.3133 | | |
| Total | 15 | 3.8783 | | | |

**Variate: April %TW**

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| REP stratum | 3 | 0.7941 | 0.2647 | 0.27 | |
| REP.*Units* stratum | | | | | |
| BN | 1 | 0.3393 | 0.3393 | 0.35 | 0.568 |
| VAR | 1 | 0.0915 | 0.0915 | 0.09 | 0.765 |
| BN.VAR | 1 | 3.2852 | 3.2852 | 3.40 | 0.098 |
| Residual | 9 | 8.6848 | 0.9650 | | |
| Total | 15 | 13.1948 | | | |

**Variate: May %TW**

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| REP stratum | 3 | 5.5926 | 1.8642 | 2.60 | |
| REP.*Units* stratum | | | | | |
| BN | 1 | 0.0028 | 0.0028 | 0.00 | 0.952 |
| VAR | 1 | 0.5891 | 0.5891 | 0.82 | 0.388 |
| BN.VAR | 1 | 4.0301 | 4.0301 | 5.63 | 0.042 |

| | | | | | |
|---|---|---|---|---|---|
| Residual | 9 | 6.4430 | 0.7159 | | |
| Total | 15 | 16.6574 | | | |

**Variate: June %TW**

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| REP stratum | 3 | 5.120 | 1.707 | 0.75 | |
| REP.*Units* stratum | | | | | |
| BN | 1 | 0.668 | 0.668 | 0.29 | 0.601 |
| VAR | 1 | 1.884 | 1.884 | 0.83 | 0.387 |
| BN.VAR | 1 | 0.452 | 0.452 | 0.20 | 0.666 |
| Residual | 9 | 20.480 | 2.276 | | |
| Total | 15 | 28.604 | | | |

## APPENDIX 3.0 Anova Tables on Effect of Variety and Barn type on tuber rots of yam stored under different conditions.

**Variate: March %TR**

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| REP stratum | 3 | 6.007 | 2.002 | 0.27 | |
| REP.*Units* stratum | | | | | |
| BN | 1 | 2.002 | 2.002 | 0.27 | 0.614 |
| VAR | 1 | 50.056 | 50.056 | 6.82 | 0.028 |
| BN.VAR | 1 | 2.002 | 2.002 | 0.27 | 0.614 |
| Residual | 9 | 66.073 | 7.341 | | |
| Total | 15 | 126.140 | | | |

**Variate: April %TR**

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| REP stratum | 3 | 0.18443 | 0.06148 | 1.57 | |
| REP.*Units* stratum | | | | | |
| BN | 1 | 0.00000 | 0.00000 | 0.00 | 1.000 |
| VAR | 1 | 0.60062 | 0.60062 | 15.33 | 0.004 |
| BN.VAR | 1 | 0.00000 | 0.00000 | 0.00 | 1.000 |
| Residual | 9 | 0.35252 | 0.03917 | | |
| Total | 15 | 1.13758 | | | |

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**Variate: May %**

**TR**

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| REP stratum | 3 | | | | |
| REP.*Units* stratum | | | | | |
| BN | 1 | | | | |
| | | 0.04202 | 0.01401 | 0.60 | |
| | | 0.00000 | 0.00000 | 0.00 | 1.000 |
| VAR | 1 | 0.04202 | 0.04202 | 1.80 | 0.213 |
| BN.VAR | 1 | 0.00000 | 0.00000 | 0.00 | 1.000 |
| Residual | 9 | 0.21013 | 0.02335 | | |
| Total | 15 | 0.29417 | | | |

**Variate: June %TR**

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| REP stratum | 3 | 9.931 | 3.310 | 2.86 | |
| REP.*Units* stratum | | | | | |
| BN | 1 | 0.030 | 0.030 | 0.03 | 0.876 |
| VAR | 1 | 17.914 | 17.914 | 15.45 | 0.003 |
| BN.VAR | 1 | 0.030 | 0.030 | 0.03 | 0.876 |
| Residual | 9 | 10.433 | 1.159 | | |
| Total | 15 | 38.337 | | | |

## APPENDIX 4.0 Anova Tables on Effect of Variety and Barn type on tuber sprouts of yam stored under different conditions.

**Variate: March, %TS**

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| REP stratum | 3 | 3.5548 | 1.1849 | 2.29 | |
| REP.*Units* stratum | | | | | |
| BN | 1 | 3.7442 | 3.7442 | 7.23 | 0.025 |
| VAR | 1 | 3.5344 | 3.5344 | 6.82 | 0.028 |
| BN.VAR | 1 | 0.5550 | 0.5550 | 1.07 | 0.328 |
| Residual | 9 | 4.6625 | 0.5181 | | |

**Variate: May %**

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| REP stratum | 3 | | | | |
| REP.*Units* stratum | | | | | |
| BN | 1 | | | | |
| Total | 15 | 16.0509 | | | |

**Variate: April, %TS**

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| REP stratum | 3 | 10.469 | 3.490 | 0.93 | |
| REP.*Units* stratum | | | | | |
| BN | 1 | 0.740 | 0.740 | 0.20 | 0.668 |
| VAR | 1 | 9.333 | 9.333 | 2.48 | 0.150 |
| BN.VAR | 1 | 0.912 | 0.912 | 0.24 | 0.635 |
| Residual | 9 | 33.912 | 3.768 | | |
| Total | 15 | 55.367 | | | |

**TS**

| | | | | | |
|---|---|---|---|---|---|
| | | 0.8195 | 0.2732 | 0.47 | |
| | | 0.1785 | 0.1785 | 0.31 | 0.593 |
| VAR | 1 | 0.2627 | 0.2627 | 0.45 | 0.518 |
| BN.VAR | 1 | 0.0028 | 0.0028 | 0.00 | 0.947 |
| Residual | 9 | 5.2200 | 0.5800 | | |
| Total | 15 | 6.4834 | | | |

**Variate: June %TS**

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| REP stratum | 3 | 4.7614 | 1.5871 | 5.34 | |
| REP.*Units* stratum | | | | | |
| BN | 1 | 1.7689 | 1.7689 | 5.95 | 0.037 |
| VAR | 1 | 3.2580 | 3.2580 | 10.96 | 0.009 |
| BN.VAR | 1 | 0.0056 | 0.0056 | 0.02 | 0.894 |

**Variate: May %**

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| REP stratum | 3 | | | | |
| REP.*Units* stratum | | | | | |
| BN | 1 | | | | |
| Residual | 9 | 2.6744 | 0.2972 | | |
| Total | 15 | 12.4683 | | | |

## APPENDIX 5.0 Anova Tables on Effect of Variety and Barn type on Rodent and Insect Damage of yam stored under different conditions.

**Variate: March %RD**

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| REP stratum | 3 | 0. | 0. | | |
| REP.*Units* stratum | | | | | |
| BN | 1 | 0. | 0. | | |
| VAR | 1 | 0. | 0. | | |
| BN.VAR | 1 | 0. | 0. | | |
| Residual | 9 | 0. | 0. | | |
| Total | 15 | 0. | | | |

Variate: April %RD

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| REP stratum | 3 | 0. | 0. | | |
| REP.*Units* stratum | | | | | |
| BN | 1 | 0. | 0. | | |
| VAR | 1 | 0. | 0. | | |
| BN.VAR | 1 | 0. | 0. | | |
| Residual | 9 | 0. | 0. | | |
| Total | 15 | 0. | | | |

**RD**

**Variate: May %**

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| REP stratum | 3 | | | | |
| REP.*Units* stratum | | | | | |
| BN | 1 | | | | |
| | | 0.09402 | 0.03134 | 0.65 | |
| | | 0.08122 | 0.08122 | 1.69 | 0.225 |
| VAR | 1 | 0.00640 | 0.00640 | 0.13 | 0.723 |
| BN.VAR | 1 | 0.00640 | 0.00640 | 0.13 | 0.723 |
| Residual | 9 | 0.43172 | 0.04797 | | |
| Total | 15 | 0.61977 | | | |

**Variate: June %RD**

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| REP stratum | 3 | 5.949 | 1.983 | 1.48 | |
| REP.*Units* stratum | | | | | |
| BN | 1 | 1.776 | 1.776 | 1.32 | 0.280 |
| VAR | 1 | 10.808 | 10.808 | 8.04 | 0.020 |
| BN.VAR | 1 | 0.200 | 0.200 | 0.15 | 0.708 |
| Residual | 9 | 12.097 | 1.344 | | |
| Total | 15 | 30.830 | | | |

**APPENDIX 6.0 Weekly average Temperature (T°C) and Relative Humidity (RH %) readings inside and outside the Circular Barn.**

CIRCULAR BARN

| Weeks | ToC cb | ToC Am | RH% Am | RH%CB | Key | |
|---|---|---|---|---|---|---|
| 1 | 30.9 | 33.2 | 51.3 | 54.7 | ToC cb | Temperature inside circular barn |
| 2 | 29.2 | 32.2 | 40.79 | 41.8 | ToC Amb | Ambient temperature |
| 3 | 30.1 | 33.24 | 41.8 | 43.6 | RH%Amb | Relative Humidity for Ambient |
| 4 | 25.8 | 33.14 | 58.19 | 59.9 | RH% CB | Relative Humidity inside Circular barn |
| 5 | 29 31.7 | 63.9 | 66.4 | | | |
| 6 | 28.2 | 27.2 | 58.25 | 72 | | |
| 7 | 28.8 | 31.53 | 61.07 | 64.5 | | |
| 8 | 27.9 | 31.18 | 71.34 | 72.9 | | |
| 9 | 28.9 | 32.09 | 63.18 | 66.9 | | |

**Variate: May %**

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| REP stratum | 3 | | | | |
| REP.*Units* stratum | | | | | |
| BN | 1 | | | | |

| | | | | |
|---|---|---|---|---|
| 10 | 28.9 | 31.75 | 66.06 | 67.7 |
| 11 | 28.9 | 32.32 | 66.26 | 68.1 |
| 12 | 28.6 | 31.59 | 67.52 | 70.5 |
| 13 | 28.2 | 31.16 | 69.98 | 72.1 |
| 14 | 27.6 | 29.96 | 74.23 | 75.5 |
| 15 | 27.5 | 29.83 | 75.73 | 76.5 |
| 16 | 26.1 | 28.2 | 79.32 | 79.9 |
| 17 | 26.3 | 29.44 | 77.06 | 80.8 |

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**APPENDIX**

**7.0 Weekly average Temperature (TºC) and Relative Humidity (RH %) readings inside and outside the Rectangular Barn**

RECTANGULAR BARN

| Weeks | ToC RB | ToC Am | RH%RB | RH%Amb |
|---|---|---|---|---|
| 1 | 31 | 33.2 | 53.2 | 51.3 |
| 2 | 29.6 | 32.2 | 39.4 | 40.79 |
| 3 | 30.7 | 33.24 | 40.4 | 41.8 |
| 4 | 30.5 | 33.14 | 57 | 58.19 |
| 5 | 29.4 | 31.7 | 63.5 | 63.9 |
| 6 | 28.6 | 27.2 | 68.9 | 58.25 |
| 7 | 29.3 | 31.53 | 61.5 | 61.07 |
| 8 | 28.3 | 31.18 | 69.6 | 71.34 |
| 9 | 29.1 | 32.09 | 64.7 | 63.18 |
| 10 | 29 | 31.75 | 65.7 | 66.06 |
| 11 | 29.3 | 32.32 | 65.7 | 66.26 |
| 12 | 28.9 | 31.59 | 68.4 | 67.52 |
| 13 | 28.5 | 31.16 | 70.1 | 69.98 |
| 14 | 27.8 | 29.96 | 73.4 | 74.23 |
| 15 | 27.6 | 29.83 | 74.6 | 75.73 |
| 16 | 26.3 | 28.2 | 78 | 79.32 |

Key
- ToC RB Temperature inside rectangular barn.
- ToC Amb Ambient temperature.
- RH%Amb Relative Humidity for Ambient.
- RH% RB Relative Humidity inside rectangular Barn.

**APPENDIX 8.0 Data on percentage rots in the Circular Barn.**

| **STRUCTURE TYPE** | **MONTHS** | | | | | |
|---|---|---|---|---|---|---|
| Circular Barn | **FEBRUARY** | **MARCH** | **APRIL** | **MAY** | **JUNE** | |
| Yam Varieties | 21/02/15 | 20/03/15 | 17/04/15 | 15/05/15 | 12/6/2015 | |
| CBPR1G1 | 0 | 0 | 1 | 1 | 3 | |
| R2G1 | 0 | 1 | 0 | 0 | 0 | |
| R3G1 | 0 | 1 | 1 | 0 | 1 | |
| R4G1 | 0 | 1 | 2 | 0 | 2 | |
| Total | 0 | 3 | 4 | 1 | 6 | 14 |
| No of Tubers | 60 | 60 | 40 | 40 | 40 | 240 |
| % Rots | | 5 | 10 | 2.5 | 15 | 5.83 |
| CBDR1G1 | 0 | 0 | 0 | 0 | 0 | |
| R2G1 | 0 | 0 | 0 | 0 | 0 | |
| R3G1 | 0 | 0 | 0 | 0 | 0 | |
| R4G1 | 0 | 0 | 0 | 0 | 0 | |
| Total | 0 | 0 | 0 | 0 | 0 | |
| No of Tubers | | | | | | |
| % | | | | | | 0 |

**APPENDIX**

**9.0 Data on percentage rots in the Rectangular Barn.**

| **STRUCTURE TYPE** | | | **MONTHS** | | | |
|---|---|---|---|---|---|---|
| Rectangular Barn | FEBRUARY | MARCH | APRIL | MAY | JUNE | |
| Yam Varieties | 21/02/15 | 20/03/15 | 17/04/15 | 15/05/15 | 12/6/2015 | |
| RBPR1G1 | 0 | 1 | 0 | 0 | 4 | |
| R2G1 | 0 | 0 | 1 | 1 | 0 | |
| R3G1 | 0 | 1 | 1 | 0 | 1 | |
| R4G1 | 0 | 0 | 1 | 0 | 2 | |
| Total | 0 | 2 | 3 | 1 | 7 | 13 |
| No of Tubers | 60 | 60 | 40 | 40 | 40 | 240 |
| % | | 3.333333 | 7.5 | 2.5 | 17.5 | 5.42 |
| RBDR1G1 | 0 | 1 | 0 | 0 | 0 | |
| R2G1 | 0 | 0 | 0 | 0 | 0 | |
| R3G1 | 0 | 0 | 0 | 0 | 0 | |
| R4G1 | 0 | 0 | 0 | 0 | 0 | |
| Total | 0 | 1 | 0 | 0 | 0 | 1 |
| No of Tubers | 60 | 60 | 40 | 40 | 40 | 240 |
| % | | | | | | 0.42 |

**APPENDIX 10.0 Data on percentage (%) weight loss in the Circular Barn for *'Pona'* and *'Dente'***

CIRCULAR BARN INFORMATION ON PERCENTAGE (%) WEIGHT LOSS

| CODE | **15/02/15** | **20/03/15** | **17/04/15** | **15/05/15** | **12/6/2015** |
|---|---|---|---|---|---|
| CBPR1G1 | 23.6 | 21 | 13 | 12 | 7.9 |
| R2G1 | 24 | 21.2 | 11.5 | 9.9 | 9.5 |
| R3G1 | 23.7 | 21.3 | 13.8 | 12.8 | 11.2 |
| R4G1 | 23.3 | 20.3 | 16.8 | 13.2 | 10 |
| | **94.6** | 83.8 | 55.1 | 47.9 | 38.6 |
| Average Tuber W.t | 1.576667 | 1.396667 | 1.3775 | 1.260526 | 1.2451613 |
| % tuber weight loss | | | | | 53.796617 |
| CBDR1G1 | 25 | 23 | 12.7 | 10.8 | 11.8 |
| R2G1 | 22.5 | 21 | 12 | 12 | 13.5 |
| R3G1 | 24 | 22.5 | 12.5 | 11.5 | 11.3 |
| R4G1 | 25 | 22.5 | 13.9 | 13 | 12.4 |



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|---|---|---|---|---|---|
| | 96.5 | 89 | 51.1 | 47.3 | 49 |
| Average Tuber W.t | 1.608333 | 1.483333 | 1.2775 | 1.1825 | 1.1136364 |
| % tuber weight loss | | | | | 45.722798 |

**11.0 Data on Percentage (%) Weight Loss in the Rectangular Barn for *'Pona'* and *'Dente'***

**RECTANGULAR BARN PERCENTAGE (%) WEIGHT LOSS**

| CODE | **15/02/15** | **20/03/15** | **17/04/15** | **15/05/15** | **12/6/2015** |
|---|---|---|---|---|---|
| RBDR1G1 | 20.5 | 19.5 | 16.2 | 10.8 | 10 |
| R2G1 | 23 | 20 | 12 | 10.2 | 9 |
| R3G1 | 22 | 20.7 | 11.5 | 10.5 | 7.7 |
| R4G1 | 21 | 19.5 | 11.3 | 10.3 | 8.5 |
| | 86.5 | 79.7 | 51 | 41.8 | 35.2 |
| Average Tuber W.t | 1.441667 | 1.32833 | 1.275 | 1.045 | 0.9777778 |
| % tuber weight loss | | | | | 45.806358 |
| | | | | | |
| RBPR1G1 | 24.7 | 21 | 9 | 9.6 | 8.9 |
| R2G1 | 20.5 | 19 | 12.3 | 11.2 | 8.5 |
| R3G1 | 23.5 | 20.4 | 10 | 9.8 | 4.9 |
| R4G1 | 24 | 22.8 | 10.8 | 10.4 | 11.9 |
| | 92.7 | 83.2 | 42.1 | 41 | 34.2 |
| Average Tuber W.t | 1.545 | 1.38667 | 1.10789 | 1.205882 | 1.1032258 |
| % tuber weight loss | | | | | 55.806796 |

**APPENDIX 12.0 Data on percentage (%) Rodent and Insect Damage in the Circular and Rectangular Barn for *'Pona'* and *'Dente'***

% Rodent Damage

| **STRUCTURE TYPE** | : R | | **MONTHS** | | |
|---|---|---|---|---|---|
| MONTHS | **FEBRUARY** | **MARCH** | **APRIL** | **MAY** | **JUNE** |
| Yam Varieties | 21/02/15 | 20/03/15 | 17/04/15 | 15/05/15 | 12/6/2015 |
| RBPR1G1 | 0 | 0 | 0 | 0 | 2 |
| R2G1 | 0 | 0 | 0 | 0 | 0 |
| R3G1 | 0 | 0 | 0 | 0 | 2 |
| R4G1 | 0 | 0 | 0 | 0 | 0 |

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| | | | | | | |
|---|---|---|---|---|---|---|
| Total | 0 | 0 | 0 | 0 | 4 | |
| No of Tubers | 60 | 60 | 40 | 40 | 40 | 240 |
| % Rodent Damage | | | | | | 1.667 |

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% Rodent Damage STRUCTURE TYPE:
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| | | | **MONTHS** | | |
|---|---|---|---|---|---|
| MONTHS | FEBRUARY | MARCH | APRIL | MAY | JUNE |
| Yam Varieties | 21/02/15 | 20/03/15 | 17/04/15 | 15/05/15 | 12/6/2015 |
| CBPR1G3 | | | | | 3 |
| CBPR2G2 | | | | | 4 |
| CBPR3G3 | | | | | 1 |
| CBPR2G4 | | | | | 3 |
| Total | | | | | 11 |
| No of Tubers | 55 | 27 | 35 | 42 | 159 |
| % Rodent Damage | Circular Barn | | | | 6.9182 |

**Appendix 13.0 Data comparing the effects of monthly average Relative Humidty inside both barns on percentage sprouting of stored *Pona* and *Dente*.**

| **Months** | CB % RH | RB %RH | Pona CB%SP | DenteCB%SP | PonaRB% | DenteRB%SP |
|---|---|---|---|---|---|---|
| March | 52.9 | 50 | 28.3 | 45 | 45 | 53.3 |
| April | 68.8 | 66 | 55 | 87.5 | 55 | 87.5 |
| May | 71.6 | 69 | 70 | 77.5 | 72.5 | 80 |
| June | 79.1 | 77 | 75.5 | 95 | 62.5 | 80 |

**Appendix 14.0 Data comparing the effects of monthly average Temperatures inside both barns on percentage sprouting of stored *Pona* and *Dente*.**

| **Months** | **CBToC** | **RB ToC** | **Pona CB%SP** | **DenteCB%SP** | **PonaRB% SP** | **DenteRB%SP** |
|---|---|---|---|---|---|---|
| March | 28.46 | 29.76 | 28.3 | 45 | 45 | 53.3 |
| April | 28.48 | 28.93 | 55 | 87.5 | 55 | 87.5 |
| May | 28.83 | 28.63 | 70 | 77.5 | 72.5 | 80 |
| June | 26.63 | 26.87 | 75.5 | 95 | 62.5 | 80 |