# EVALUATION OF QUALITY OF WHITE YAM CULTIVARS (*PONA* AND *DENTE*) IN TWO IMPROVED TRADITIONAL STORAGE STRUCTURES



BY

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## DECLARATION

I hereby declare that this submission is my own work towards the Msc. and that, to the best of my knowledge, it contains no material previously published by another person, nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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**ABSTRACT**

Harvested yams are often stored in structures such as barns. The poor conditions of most barns usually lead to storage losses due to rot, weight loss, sprouting etc. To curb this situation, two improved traditional barns were introduced. Despite the efficiency of these new barns, their effect on food quality of stored yams has not been studied. This study therefore aimed to evaluate the temperature and relative humidity in two improved barns (rectangular and circular) and to determine the effect of the barns on the physical, chemical and sensory properties of two yam cultivars; *pona* and *dente* stored for six months. A total of 240 tubers of each cultivar were used for the study. Data loggers were used to measure temperature and relative humidity inside and outside the barns. The physical parameters determined were weight loss, rotting, sprouting and rodent damage. Chemical analysis determined included proximate, starch and sugar. Sensory evaluation was carried out on the stored and hidden controlled boiled yam at the end of the storage period to assess their preference by potential consumers using the scale 1-9 with 1 being like extremely, 5- neither like nor dislike and 9 being dislike extremely. Temperature in the barns over the storage period ranged from 25.4-30.8$^oC$ in the rectangular barn and 25.4-30.4$^oC$ in the circular barn. Relative humidity in the rectangular barn ranged from 37.9-79.3% and from 40.980.7% in the circular barn. Weight loss of 23.42% and 21.94% for *pona* in circular and rectangular barns respectively were recorded at the end of the storage period. *Dente* recorded comparatively higher weight loss of 28.57% in circular barn and 26.39% in rectangular barn. Rot was seen earlier (after 1$^{st}$ month) and higher in *pona* cultivar (48.33% for both circular and rectangular barns) than *dente* (16.67%- circular, 11.67%-rectangular). In each of the cultivars sprouting started right from the first month and peaked at the fourth month. *Dente* tubers had about 51.19% and 46.96% sprout in circular and rectangular barns respectively, higher than *pona* tubers (38.85% in circular and 38.38% in rectangular barn); however, rodent damage was very minimal at the end of the storage period. There was no significant difference in the physical properties of samples stored in rectangular and circular barns. Proximate analysis revealed an average decrease in carbohydrate from 32.18g/100g to 23.81g/100g and 37.36g/100g to 23.18g/100g in *dente* and *pona* cultivars respectively in circular barn at the end of the storage period. Moisture content decreased significantly ($p>0.05$) for *dente* cultivar from 62.3g/100g to 49.9g/100g in circular barn and 48 .1g/100g in rectangular barn. Both ash and fat contents did not change significantly. After three months of storage, protein content of *pona* stored in circular barn increased significantly from 2.31g/100g to 6.13g/100g and similar observation was made for *dente* in the rectangular barn. As the starch content decreased over the storage period, the sugar content in both cultivars increased. Sugar content of *pona* was higher (from 3.91g/100g to 6.20g/100g) than *dente* (from 3.21g/100g to 4.30g/100g) in rectangular barn. Again, the different barn types did not significantly affect the chemical properties of the tubers. Between the two cultivars, *pona* was preferred (3-like moderately) based on its sensory properties against *dente* (4-like slightly). Stored yams showed better sensory properties compared to the control. To keep harvested tubers as fresh as possible, it is therefore recommendable for tubers to be stored up to about four months even in the improved barns.

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# CHAPTER ONE

## 1.0 INTRODUCTION

Yam of genus *Dioscorea* is among the staple foods in Africa, the Caribbean and the South Pacific regions**.** They are common in over 47 countries in the tropical and subtropical regions of the world with the principal producer being Nigeria (FAO, 2005; IITA, 2009). Ghana is among the first five leading exporters of yam in the world, accounting for over 94 percent of total yam exports in West Africa (MAFAP/SPAAA, 2013).

There are several varieties of yam with *D. rotundata* being the most widely grown and usually considered to be the best in terms of food quality, thus commanding the highest market value (Markson *et al.*, 2010; Otegbayo *et al.*, 2001). Varietal differences influence the quality of various traditional yam products (Akissoe *et al.*, 2001). In Ghana, within *D. rotundata* species, *Pona* and *Labreko* are rated superior to other white yam varieties such as *Asobayere* and *Muchumudu* (Addy, 2012).

Yam is an annual crop and for year round availability, they are mostly stored under different conditions after harvest for future use, either as seed yam or for consumption later in the year. They can be stored for about six months at atmospheric temperatures but with high tuber losses in traditional barn Osunde (2008). Examples of methods used to ensure year round availability are late harvesting, storage on platform and in barns and modern storage structures. Late harvesting is a method whereby yam tubers are left in ridges after maturity as a means of storage. The tubers can remain there for about four months (Knoth, 1993) but all these have not been able to mitigate the problem of post-harvest losses in yam.

According to report by MoFA (2015) though Agriculture Ministry planned to reduce postharvest losses of yam by 12% in 2012, Ghana still recorded 18.31% losses of yam. Evapotranspiration and other factors including loss of tuber moisture, sprouting, insect damage, storage conditions, fungal and bacteria rot are the major causes of post-harvest losses (Bancroft, 2000).

These are reported to affect food quality of stored tubers either negatively or positively (WirekoManu *et al*, 2013)

## 1.1 Problem Statement

The poor nature of storage structures and storage environments are among the major conditions that causes excessive loss of yam during storage. Under traditional storage systems losses could go up to about 30-50%. Researchers have improved on the different methods of storage but most structures are susceptible to insect and rodent attack, which results in greater product loss as their bite pave way for infestation by rot bacteria. In addition, storage environment basically temperature and relative humidity contribute to physiological factors such as transpiration, respiration and sprouting. Even though the structures in this work are improved by constructing with wooden boards that are resistant to termite attack, elevating the floor fitted with rodent guards, roofed with thatched grass, providing shelves on which tubers are placed and vents for ventilation; their impact on food quality have not been determined.

## 1.2 Justification

Extending shelf life and ensuring availability of food all year round is a key to food security in developing countries. One way to achieve this is to know the storage life and the best way to extend it if possible. The results obtained from this study will provide information on yam qualities during storage and the effects of improved traditional storage structures on storage length and food quality of yam.

## 1.3 OBJECTIVES

To determine the storage length and quality characteristics of white yam cultivars (*Dente* and *Pona*) in two improved types of storage structures over a period of six months.

### 1.3.1 Specific Objectives

The specific objectives of this study are to:

I. Evaluate the temperature and relative humidity in the improved structures.

II. Determine the effect of two improved storage structures on the physical, chemical and sensory properties of yam tubers stored over a period of six months.

# CHAPTER TWO

## 2.0 LITERATURE REVIEW

Yam is the common name for some species in the genus *Dioscorea* (family *Dioscoreaceae*). Yam (*Dioscorea* spp) is a climbing plant with smooth leaves and twining stems, which coil readily around a stake (Udensi *et al*., 2008). It is a tuber crop and as compared to other root and tuber crops, yam production is relatively expensive; due to high cost of labour and planting material. Yams are planted by yam mini-sets (small pieces of yam), or whole tubers (seed yam). The tubers are kept after harvest for use in the next planting season.

Yam is a delicacy and staple food in most West African countries. (Opara, 1999) stated that apart from cereals, yam is one of the important food crops in West Africa. Yam is ranked third among consumers‟ preference after cassava and sweet potato (Fu *et al*, 2005). But it is ranked the most second important tropical tuber crop in West Africa after cassava (Osunde, 2008; Opara, 1999).

The West Africa sub-region contributes about 90-95% of yam produced globally. Ghana is the third largest producer of yams in the world, after Nigeria and Cote d‟Ivoire. Ghana produced approximately 5million metric tonnes of yam in 2008, compared to approximately 35 million metric tonnes produced in Nigeria and 7 million metric tonnes produced in Cote d‟Ivoire (FAOSTAT, 2010).

Out of the over 500 species of yam, only about 6 of them are considered edible while some of the non-edible ones are produced for industrial use (Mijinyawa and Alaba, 2013; IITA, 2008). The few important species which serve as staples include yellow yam (*D. Cayensis)*, water yam (*D. alata*), white yam (*D. rotundata*), trifoliate yam (*D. dumetorum*), Chinese yam (*D. esculenta*) and aerial yam (*D. bulbifera*) (Hahn *et al.*,1987). The size and shape of tubers may vary based on the species and environmental conditions. The tuber of white yam is usually cylindrical in shape with smooth and brown skin and a white firm flesh (Djeri *et al*., 2015).

## 2.1 IMPORTANCE OF YAM

Yams are mostly cultivated for human consumption and are sold as fresh tubers in all the growing areas. Boiling, frying and baking are the popular methods of preparation. As reported by Opara (2003), boiled yams can be pounded and eaten as „*fufu*‟ or „*utara*‟ while baked yams are eaten with palm oil or vegetable sauce. Fried yam-balls are also prepared from the fresh tuber by first grating the peeled tuber, spicing the grated tuber and frying portions of it in hot oil to form little balls.

Yam may be processed into different food products including yam flour. Processing and utilization of yam in the industry includes poultry and livestock feed as well as starch. Sifting of yam leaves residues which are fed to animals together with the peels in most local communities (Opara, 2003).

The wide consumption of yam is also as a result of its nutritional benefit. They have generally high moisture and dry matter composed of vitamins, starch, minerals, etc. Trace amounts of phenolic compounds (e.g. Tannins), steroid-based compounds (e.g. diosgenin) and alkaloids (e.g. dioscorine) may also be present in yam (Muzac-Tucker *et al.*, 1993). The nutritional composition of yams is summarized in table 2.1.

**Table 2.1: Nutritional Assessment of yam**

| **Nutrient (unit)** | **Amount in tuber** |
|---|---|
| Calories | 71.00-135.00 |
| Moisture (%) | 65–81 |
| Protein (g) | 1.4-3.5 |
| Fat (g) | 0.20-0.40 |
| Carbohydrate (g) | 16.40-31.80 |
| Fibre (g) | 0.40 - 10.00 |
| Ash (g) | 0.60 - 1.70 |

| | |
|---|---|
| Calcium (mg) | 12.00 - 69.00 |
| Phosphorus (mg) | 17.00 - 61.00 |
| Iron (mg) | 0.70 - 5.20 |
| Sodium (mg) | 8.00 - 12.00 |
| Potassium (mg) | 294.00 - 397.00 |
| b-carotene eq. (mg) | 0.00 - 10.00 |
| Thiamin (mg) | 0.01 - 0.11 |
| Riboflavin (mg) | 0.01 - 0.04 |
| Niacin (mg) | 0.30 - 0.80 |
| Ascobic acid (mg) | 4.00 - 18.00 |

Source: Opara (2003)

Some species such as *D. hispida* and *D. dumetorum* are used in hunting since they contain dioscorine and dihydrodioscorine respectively which are alkaloids. These alkaloids poison the nerves of the organisms during hunting and fishing. *D. mexicana, D. floribunda, and D. composite* are widely grown in Mexico for pharmaceutical purposes where they contain small amounts of sapogenins. Sapogenins and saponins are precursors of cortisone which are used intreatment of arthritis and some allergic reactions (Markson *et al.*,2010; Ezeocha and Onwuka, 2012).

Yams also have economic and social values for everyone involved in its food chain comprising rural poor producers, processors and consumers (Babaleye, 2005). Economically, it is an income generating crop in many African countries (FAO, 2008). Social values of yam are celebrations of traditional festivals, focusing on the eating of new yam in certain areas of West Africa. It is also a custom in some parts of Africa for the parents of a bride to offer yams for planting as a resource to assist them in raising a family (Opara, 2003).

## 2.3 POSTHARVEST CHALLENGES OF YAMS

The major postharvest challenge of yam is the faster rate at which it deteriorates.

### 2.3.1 Post-harvest losses of yams

Attempts by breeders to increase production of yam by various methods are becoming futile since gains in production are lost from the time of harvesting the crops till it gets to the consumer (Okigbo, 2004). This has become a major challenge leading to food insecurity because root and tuber crops like cassava, yam, and cocoyam are important crops in terms of food security and income generation for most African countries (AMCOST 2006; FAO 1998). Millions of people are dependent on these crops not only for food but for income as well. Hence, losses associated with these crops affect livelihood of farmers thereby intensifying the rate of poverty in rural areas (Ntiokwana, 1999) as cited in (Thamaga-Chitja *et al*. 2004).

Postharvest losses of tuber crops are more serious in developing countries than those in developed countries due to handling procedures not fully recognized and production not linked with marketing. However, with tuber crops such as yam, proper storage facilities, transport and handling technologies are practically non-existent hence substantial amount of the produce are lost. So much time is devoted to the cultivation of the crop only to be wasted due to poor storage facilities, poor road network and poor handling methods adopted by the farmer from the production centre to the point of planting until the produce reach the consuming public (Bencini, 1991).

Researchers have estimated post-harvest loss in yam during harvesting, transportation, processing and storage to be about 60% as reported by (Asiedu, 1986; Coursey and Booth, 1997; Wheatley, 2000; Alabadan, 2002). These percentage losses may however be further decreased through the use of appropriate storage methods since most of these causes are either external agents, such as insects, rodents, fungi and bacteria or physiological processes, such as sprouting, transpiration, respiration and germination (Wilson, 1980).

### 2.3.2 Causes of post-harvest losses of yams

#### 2.3.2.1 Pest

Pests such as insects cause post-harvest losses to yams. They do so by burrowing the tubers thus decreasing the wholesomeness of the yam. Insects damage the epidermis making it accessible by mold and bacteria which eventually leads to rot (FAO, 1998). The major insect pests which cause destruction of yam in Ghana are termites, yam beetles, yam scales and vine beetles.

Termites reduce the percentage of setts that sprout by eating out the "eye" of the planted setts. Furthermore, they damage the growing tubers by making unsightly tunnels in them (Ogundaria, 1998). Also the citrus mealy bug, *Planococcus citri*, has been observed as pest of yam tubers in the field and in storage (Ogundaria, 1998).

#### 2.3.2.2 Pathogens

Pathogens such as fungi, bacteria, and nematodes cause post-harvest losses of yam tubers through rotting. Yam tuber rot is mostly caused by pathogenic fungi. Normally, fungi that do cause rot depend on the lesions or wounds to enable them penetrate the tubers to cause rot (Okigbo and Emoghene, 2004). Nematodes cause damage to the growing region just beneath the tuber skin so that the affected tubers are very poor if used as planting material. The root-knot nematode gives the skin of the crop a warty appearance. The holes in tubers reduce market value (Ogundaria, 1998). Rottenness affects attributes like the consistency and flavour of the yams rendering the tuber unwholesome for consumption while causing huge loss in market value.

**2.3.2.3 Respiration and Temperature conditions:**

Roots and tubers also respire as all living organisms do. The extent of respiration has been shown to be positively correlated with temperature. Tubers and other crops cultivated in the tropics are associated with high losses due to uncontrolled high temperatures in the region (Olasantan, 1999). The unstable climates in Ghana characterized by high temperatures have affected the cultivation and storage of yam and other root and tubers. Temperature reduction below 20$^{o}$C has been observed to significantly reduce the respiration rate in tuber yams during storage thereby minimizing moisture loss (Ravi *et al.*, 1996).

**2.3.2.4 Sprouting**

Sprouting is one of the physiological causes of storage losses in yam. The occurrence of sprout is characterized by the conversion of edible tuber components into inedible parts and is often considered a post-harvest loss. Usually, sprouting is enhanced by increase in storage temperature (Kader, 2004). Sprouting of yams that are meant for consumption is unacceptable because the process result in loss of carbohydrate, sugar, and other nutrient contents in the yam tubers (Afoakwa and Sefa-Dedeh, 2001). The more the nutrients such as carbohydrates are lost, the smaller the yam becomes in terms of size, and less the price of the yam (Ravi and Aked, 1996). Traditional means of controlling sprout has involved removal of the emergent sprouts when they are about 30 mm long (unless the tubers are needed for planting). Sprouts removal at monthly intervals reduces fresh tuber weight loss within 5-month storage period by 11% in *D. rotundata* and *D. alata* tubers (Osunde *et al.*, 2003).

#### 2.3.2.5 Transportation

The major problems facing yam farmers in Ghana are poor road network leading to the producing areas and inadequate transport facilities. This sometimes leads to loss of crops as most of the produce is left in the farm. Sometimes the impassable poor road network causes bruises to the tubers when they are being transported from farms to market places. Losses directly attributed to transport conditions are very high (Kumah and Olympio, 2009).

## 2.4 STORAGE OF YAM

Yam is an annual crop and it is expedient that excess harvested yams are stored to ensure availability while waiting for the next harvesting period. Compared to other tropical produce, yams store longer and as such are considered a more viable option by farmers and marketers (Iwuchukwu and Onwubuya, 2012). The storage of yam is dependent on their dormancy which usually begins after their physiological maturity (Knoth, 1993).

Dormancy can be defined as a condition of rest when metabolic processes like respiration, enzyme activity, starch and sugar metabolism are minimal (Hamadina, 2011), and in yam tubers under storage, it is marked by the absence of sprout. Understanding the length of dormancy for stored tubers is essential since at the break of dormancy, the tubers rapidly senescence with loss of the stored food (carbohydrate) (Panneerselvam *et al.*, 2007). The length of dormant period is influenced by species variation. This knowledge is important for designing appropriate storage and marketing strategies, and also for deciding the next planting time. Table 2.2 shows the dormancy period of tubers of major edible yam species.

**Table 2.2: Dormancy period of tubers of major edible yam species (Nigeria locality)**

| Species | Period of dormancy (weeks) |
|---|---|
| *D. alata* | 14-16 |
| *D. cayenensis* | 4-8 |
| *D. dumetorum* | 14-16 |
| *D. esculanta* | 12-18 |
| *D. rotundata* | 12-14 |

**Source: Opara (1999)**

### 2.4.1 Curing of yams

Curing is mostly done prior to storage of yams in order to “heal” physical damages which may have occurred during harvesting or in handling of the tubers. It allows suberisation of surface injuries and hinders subsequent loss of weight and rotting in root crops. Yams are cured traditionally by sun drying the tubers for few days. Temperature range of 29$^{o}$C-32$^{o}$C and relative humidity of 90-96% are considered optimum for the curing of yams, (McGregor 1987). It is also reported that, curing tubers above 40$^{o}$C for 24 hours or treatment with gamma radiations at 12.5krad significantly reduces mold growth and minimizes storage losses, (McGregor 1987). Storage of yams at 15$^{o}$C accompanied with prompt removal of sprouts has been found to significantly improve the eating quality of tubers probably due to the inhibition of biochemical synthesis accompanying sprouting and associated water loss (Okigbo, 2004)

## 2.5 LOSSES OF YAM IN STORAGE

There are several techniques developed to store yam well, but the little documentary evident available on the magnitude of storage losses suggest that, substantial losses occur. It has been observed that yam losses vary considerably in magnitude from country to country, region to region, species to species and even variety to variety. The losses that occur during storage even under the best conditions are much more serious than is generally realized. Although, there is a great variation among varieties, losses in weight of 10 – 20% after only three months storage and 30 – 60% after six months are not unusual even for sound tubers, and even greater losses occur if infection by rotten organisms takes place (Ogali *et al*, 1991).

## 2.6 TYPES OF STORAGE SYSTEMS

Various storage systems have been developed to reduce the losses of yam.

### 2.6.1 Traditional storage systems

#### 2.6.1.1 Storage in barns

Yam barns are the main traditional storage structures in major yam producing communities. In humid forest zones, they are constructed under shades in a manner so as to enable enough ventilation and protect tubers from insect damage, direct sun radiation and flooding. Traditional barns are basically made of wooden framework to which tubers are singly attached even though several designs do exist, (Opara, 1999; Igbeka, 1985).

The tubers are rope-tied and hanged on horizontal poles about 2m high. The ropes are often fibrous and in some parts of Nigeria, they are made from raffia obtained from upper parts of palm trees. Most farmers keep permanent barns and provide annual maintenance. In such situations, they use growing trees as vertical poles and trim them periodically and provide shades made of palm fronds. The trees also provide additional shade for the tubers from excessive sunlight and rain. According to Opara (2003), yams stored in barns have a maximum storage life of six (6) months. Storage losses can be as high as 10-15% in the first 3 month of storage and up to 50% by the end of six months if tubers are not treated with fungicides such as Captan or thiabendazole.

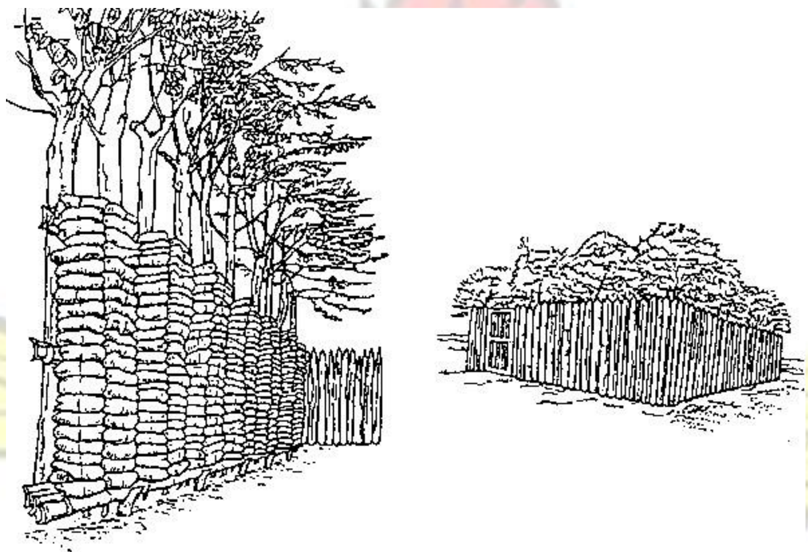


**Fig 2.1 Typical Traditional Yam Barn (Diop and Calverley, 1998)**

Barns are very effective for yam storage in the dry season but in the rainy season, stored tubers deteriorate rapidly as the constantly moist environment promotes and results in rotting of tubers and deteriorates the framework of the barns (Nwaigwe *et al*., 2015). The rains also facilitate spreading of diseases to healthy tubers especially those in the lower tiers. For this reason, at the onset of the rainy season farmers move their tubers indoors and store them on floors or shelves (Ofor *et al.*, 2010).

#### 2.6.1.2 Leaving Yam tubers in the ridges after maturity

Yams reach maturity when vegetative growth ceases and the dry matter of the vine is converted to tubers and then enters a dormant or resting stage. This maturity is often observed at the beginning of the dry season when leaves turn yellow (FAO, 1998). This physiological maturity usually takes about 8 to 11 months after planting and then are ready to be harvested. In some areas, matured tubers are left in ridges for up to 4 months as a form of storage depending on the variety of the yam. This storage method is cheaper as no cost of raising a store is required. However, the yams are not protected from damage from pests and other animals as other stores do (Ofor *et al*., 2010)

#### 2.6.1.3 Underground storage

Yams may also be stored in underground structures such as ditches, clamps or pits. Such underground structures are unable to store yams for longer periods compared to other structures and as such are more suitable for tubers that are intended for limited storage periods. The temperature in the underground storage space is often moderated by covering with cut vegetables. Yams stored in these storage structures are prone to rodent attack and may not have enough ventilation (Opara, 2003), however research has shown that, yams stored in underground structures perform better than those stored in the open shed.

#### 2.6.1.4 Storage in Trench Silos

Yams are also stored in silos constructed in or on the sides of fields especially in yam fields that are located far from human settlements. This practice saves labour which can then be channeled into other ventures especially during harvest. These silos are constructed by digging a pit with size proportional to expected yam harvest. The pit is lined with straw or other similar material and the tubers are then laid on the straw horizontally or vertically with the tip facing downward. The tubers are then covered with straw, sometimes; a layer of earth is added. Major shortfall of this storage system is lack of adequate ventilation which causes buildup of heat in stored produce and thus promoting the formation of rot. The design of the silos does not permit regular monitoring of the stored produce and also permit easy accessibility by rodents which subsequently cause damage to the stored yams (Ofor *et al.*, 2010).

#### 2.6.1.5 Platform Storage Yams

Yams are also stored on raised platforms constructed on the field. The tubers are arranged vertically or horizontally but no tuber is placed on top of the other. Farmers who adopt this storage system are often faced with challenges regarding ventilation and inspection of the tubers especially if tubers are arranged vertically and are stacked several layers deep. For traditional barn storage, storage with outdoor platform is discontinued when the rainy season begins, (Ofor *et al.*, 2010).

### 2.6.2 Improved Structures for Storage of Yams

Despite the popularity of traditional barns in West Africa, it has not been very effective in its aim of keeping yams in fresh state after storage. Much of its inefficiencies are due to the fact that stored yams are prone to attack by rodents and other animals. Restriction of ventilation and energy-consuming task of having to tie the yam around the structures have all been underscored as some of the shortfalls in these traditional barns, (Diop and Calverley, 998). Attempt to overcome these limitations has brought into existence several other improved barns used for yam storage.

#### 2.6.2.1 Open-sided Shelves

This structure, as recommended by the Nigerian Stored Product Research Institute, NISPRI, (1982) is similar to traditional barn types except that the yams are arranged on shelves instead of being tied to the structures in the traditional type. These barns are simple and easy to operate. They also allow for easy inspection during storage and removal of sprout as well. Yams stored in such barns are however, still prone to adverse effects of radiations and rodent attack making it necessary for additional provision of shed and other barriers.

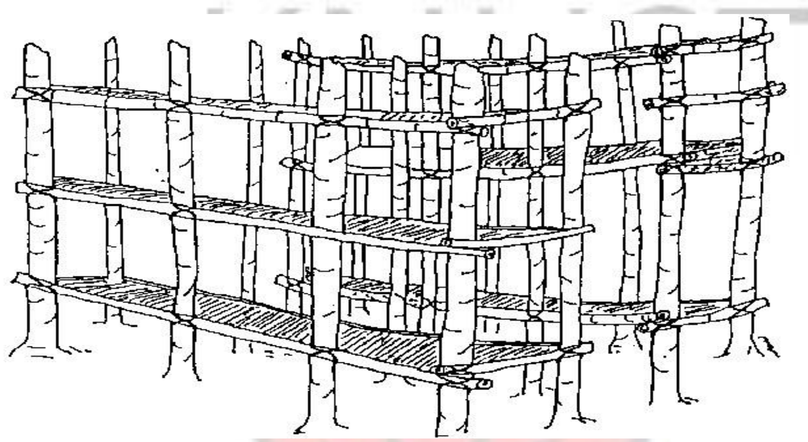


**Fig 2.2 Simple Wooden Shelves for Yam Storage (NISPRI, 1982)**

**2.6.2.2 Elevated Shed-Store**

These barn types are made of elevated floors fitted with rat guards with thatched roof covering. There is minimized radiation and rodent damage in such barns but ventilation is still of much concern as yams are mostly not arranged on shelves, (Diop and Calverley, 1998). These shelves are mostly designed to store up to two tonnes of yam. The early trials of these barns showed that, they are able to keep storage losses at a minimal rate of 22.4% as against 38.4% in traditional barns.

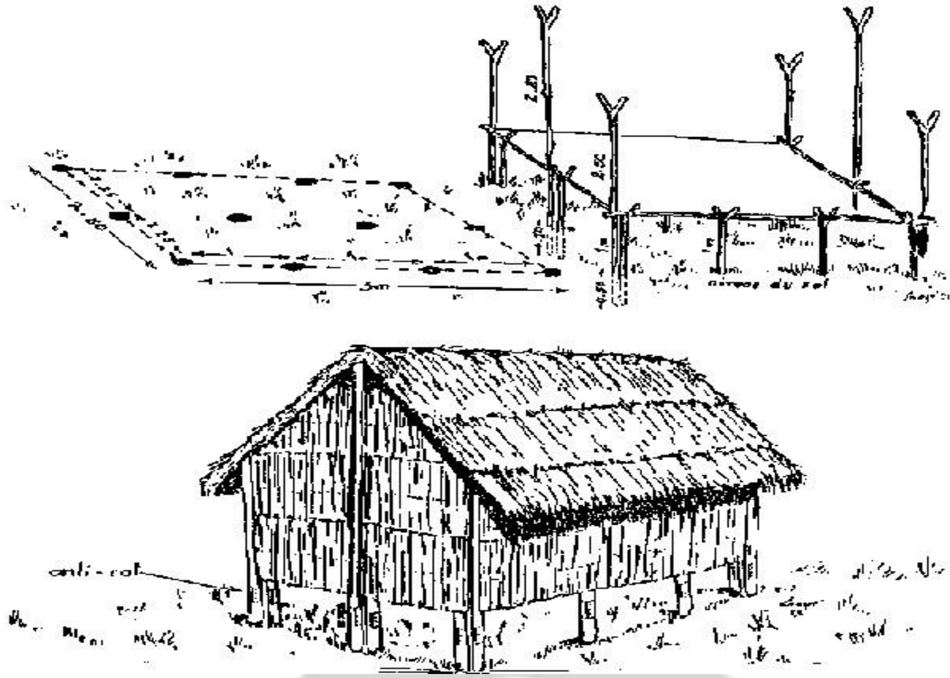


**Fig 2.3 Elevated Shed store (Fiagan, 1995)**

Other improved barn types such as the ventilated pit store and the thatched roof pit store have also been proposed and recommended for as an alternative for traditional barns in the storage of yams. However, these are very expensive barns to construct and as such are mostly not economically feasible for the local producers.

### 2.6.3 Techniques for extending Dormancy in Stored Yams

Successful storage of yams is normally dependent on several factors including; use of healthy tubers and proper curing accompanied with fungicide treatment, regular inspection and removal of sprouts, ensuring ventilation and protection from direct sunlight and rain (FAO, 1998) Researchers have focused on several methods and techniques to improve yam storage. Such techniques are generally aimed at extending dormancy in the yam tubers in order to obtain almost fresh yams even after storage.

### 2.6.3.1 Irradiation

Different intensities of gamma irradiation offer technical advantages for storing yam tuber for fresh consumption (IBansa and Appiah, 1999; Vasudevan and Jos 1992). Work done by Bansa and Appiah, (1999) showed that average dose of 120 Gy and a dose rate of 114 Gy/hr when applied to *D. rotundata* cultivar was able to reduce sprouting after six months of storage. However, differences in varietal responses to irradiation have also been reported by (Vasudevan and Jos, 1992).

### 2.6.3.2 Chemicals

Chemical compounds have been used to extend dormancy and inhibit sprouting (Gerardin *et al.*, 1998a; IITA, 2007; Orhevba and Osunde, 2006). Gibberillic acid (GA) when applied to tubers soon after harvest is able to extend dormancy up to about 11 weeks for *D. rotundata* and up to 13 weeks for *D. alata* species of yam tuber according to (Gerardin *et al.* 1998a and IITA 2007). Eze (2011) also reported a longer dormancy period in stored *D. rotundata* using Gibberillic acid. Chloroisopropylphenylcarbamate (CIPC) solution and powder which have been successfully used to inhibit dormancy in stored potato tubers did not show any significant effect on *D. rotundata*, (Orhevba and Osunde, 2006).

Nair (1982) showed that soaking tubers of *D. esculenta* and *D. rotundata* in 1000 ppm solutions of maleic hydrazide for ten hours before storage reduced the rate of sprouting by 16% and 8% in *D. esculenta* and *D. rotundata* respectively. Other chemicals used in yam storage include commercial wax, lime, benlate and captan. The observed effects of chemicals on the storage life of yam tubers have been observed to differ based on species and cultivar differences.

## 2.7 FURTHER RESEARCH

According to Osunde (2008), the paramount objective of yam storage is to maintain the tubers in their most edible and marketable state by hindering spoilage by pathogens, insects and rodents; prevent moisture loss and inhibit sprout growth. But controlling with irradiations and some chemicals is believed to have adverse effect on consumers; likewise facilities to control storage temperature are expensive. It is therefore expedient to create improved traditional barns with cheap and locally available materials to store yam and study its effect on the yam quality.

# CHAPTER THREE

# MATERIALS AND METHODS

### 3.1 STUDY SITE

The experiment was conducted at Kasei, a village within the Ejura community in Ashanti region of Ghana. The choice of the place was based on the fact that it is a major yam growing community with most of the yam cultivated being white yam.

### 3.2 SAMPLE COLLECTION

#### 3.2.1 Source of Yam Tubers

Two cultivars of white yam *(Dente and Pona)* at nine months maturity, freshly harvested and cured were obtained from a farmer in the area of study.

#### 3.2.2 Storage Structure

Two improved traditional storage barns with different shapes (circular and rectangular) were used for the study. Materials used for the construction of the structures were durable indigenous materials of less economic value, namely wooden boards from *Borassus flabellifer* and roofed with Thatch grass (*Imperata cylindrica)*. Other materials used were *wawa* boards, aluminium roofing sheets, wire mesh and padlocks. *Borassus* was chosen due to its resistance to termite attack and adverse weather conditions, its high strength among others. The barns had shelves inside on which the tubers were arranged for easy observation, the *wawa* boards were used for the construction of the shelves. The roof of the barns was made with thatch grass which was readily available in the community; its heat absorption is minimal as compared to aluminum sheets used for most traditional storage structures. The aluminum sheets were nailed around the frames of the structures buried in the ground to serve as rodent guards to prevent entry of rodents into the storage structures. The barns had openings on their top sides serving as windows to facilitate ventilation and these were covered with the wire mesh to prevent access by pests. Padlocks were used to lock the doors of the barns to prevent theft by human. The circular barn was constructed a meter above the ground with a diameter of 3.7 meters and the rectangular barn was also a meter above the ground with a dimension of 3.7x3.0 meters.

**Plate 3.1: Circular Barns used for storage of the yam samples**

**Plate 3.2: Rectangular Barn used for storage of the yam samples**

The tubers were labeled for easy identification, weighed to obtain the initial weight and stored in the improved storage structures for the study.

**Plate 3.3: Researcher labeling tubers**

Each barn contained 480 tubers; 240 tubers of each cultivar. The tubers were put into four groups with 60 tubers in each group. Each group had four replications with fifteen tubers in each replication. Randomly, four replications were selected for each cultivar as samples for the study using simple random sampling technique. The tubers were arranged on the shelves for easy observation, weighing, and facilitation of ventilation.

**Plate 3.4 Interior part of the Shelved barn**

### 3.2.3 Monitored Parameters

Monitored parameters included temperature, relative humidity, tuber rot, tuber weight, rodent attack and sprouting. Relative humidity and temperature inside and outside the barns were monitored using a digital thermo-hygrometer logger (Tinytag Explorer View 2, Version 4.8 by Gemini data loggers (UK) Ltd). Physical observation was used to check for rodent attack, rotten and sprouting tubers. Tuber weights were taken (by weighing each replication of fifteen tubers and the average tuber weight calculated) every four weeks starting from the first day of storage using a weighing scale. The percentage weight loss for each month was calculated based on the initial tuber weight using the formula: $WL_n = (W_0 - W_n) / W_0 \times 100$

Where **WLn** =Percentage weight loss, **W0**= Initial weight of tuber (kg), Wn =Final weight of tuber (kg) Ezeike, (1984).

Sprouting rate was assessed monthly by counting the sprouted tubers. The average monthly sprouting was hence computed and the percentage calculated using the formula below.

$$\text{Sprouting index} = \frac{\textit{Number of sprouted tubers}}{\textit{Total number of Tubers}} \times 100$$

Opara, (1999)

The number of rotten tubers was recorded during weighing of the tubers by visual examination after cutting samples both transverse and longitudinal. Percentage rot was calculated as:

$$\text{Percentage Rots} = \frac{\textit{Number of Rotten tubers}}{\textit{Total number of Tubers}} \times 100$$

Opara, (1999)

Percentage of tubers damaged by rodents over the period was determined through visual examination and calculation.

$$\text{Percentage Rodents damage} = \frac{\textit{Number of damaged tubers}}{\textit{Total number of Tubers}} \times 100$$

Opara, (1999)

### 3.3 LABORATORY ANALYSIS

Chemical analysis of the stored tubers was determined during the storage period. This was done at the start before the tubers were stored, three months of storage and six months of storage.

The analyses determined were proximate, starch, reducing sugars and total sugars.

### 3.3.1 Determination of Moisture

The Official Methods of Analysis, AOAC (1990) was used to determine the moisture content. Chopped fresh yam tuber (2g) was weighed and transferred into previously dried and weighed glass dishes. The dishes with yam samples were placed in a thermostatically controlled oven and heated at 105°C for 5 hours. The dishes were removed and cooled in a desiccator and reweighed. The dishes were dried again for 30 minutes, cooled down and weighed. This procedure was repeated until constant weight was reached. The moisture content was then determined by difference and expressed as a percentage.

### 3.3.2 Determination of Protein

The content of crude protein in the yam was determined by the Kjehdahl (AOAC, 1990) method. This method involves stages of digestion, distillation and titration. Two (2) grams of yam flour was put in a digestion flask and half of selenium based catalyst with broken porcelain crucibles (anti-bumping agent) was added. Twenty five millilitres of concentrated $H_2SO_4$ was added. The flask was then shaken to obtain uniformly wet flour. The flask was heated slowly on a digestion burner until boiling ceased and a clear solution was obtained. The solution was then allowed to cool at room temperature and transferred into a 100 ml volumetric flask then topped up to the mark with distilled water. A distillation apparatus was first flushed with boiled distilled water before use and connected in such a manner as to maintain at least 10 minutes of circulation within the condenser. Twenty five millilitres of 2% boric acid was pipetted into a 250 ml conical flask and 2 drops of mixed indicator added. The solution was placed under the condenser ensuring that the tip of the condenser was fully immersed in the solution. Ten milliliters of the digested solution was measured. Forty (40) percent of NaOH was added in excess to the decomposition flask and the funnel stopcock closed. The stopcock on the steam trap outlet was shut to force steam through the decomposition chamber in order to drive the liberated ammonia into the collection flask. The distillate was titrated with 0.1 N HCl solution. The acid was added until the solution was colourless. Additional acid caused the solution to become pink. The procedure was repeated for the blank.

### 3.3.3 Determination of Ash

The ash content was determined using the Official Methods of Analysis (AOAC, 2000). Yam flour/starch (2g) was transferred into a porcelain crucible which had previously been ignited, cooled and weighed. The crucible and its contents were then placed in a muffle furnace preheated to 600°C for 2 hours after which it was removed and cooled in a desiccator and weighed.

The total ash content was expressed as percentage.

### 3.3.4 Determination of Fat

The crude fat content was determined using the AOAC (2000) method. Two grams of the dried yam flour was weighed onto a filter paper (22x80). To prevent loss of flour the thimble was blocked with a glass wool. Petroleum ether (50 ml) was added to the round bottom flask and the apparatus was assembled. With the aid of a heating mantle, the quickfit condenser connected to the soxhlet extractor was refluxed for 16 hours. The flask was removed afterwards and allowed to evaporate on a steam bath. The flask and its content were oven-heated at 150°C for 30 minutes. It was then cooled to room temperature in a desiccator and weighed. The fat content was expressed as percentage by weight.

### 3.3.5 Determination of Crude Fibre

The crude fat content was determined using the AOAC (1990) method. The defatted flour used for the crude fat determination was transferred into a 750 ml Erlenmeyer flask and approximately

0.5g of asbestos was added. 200 ml of boiling 1.25% $H_2SO_4$ was added and the flask was immediately set on a hot plate and condenser connected to the Erlenmeyer flask (cold finger type). The flask and its content were heated for 30 minutes. The content of the flask was then filtered through linen cloth in funnel and large volumes of boiling water were used to wash the content until washings was no longer acidic. This was done using a pH meter. Using 200 ml boiling 1.25% NaOH solution, the filtrate and asbestos were washed back into a flask. The flask connected to the condenser was boiled for thirty minutes and at the end the contents were filtered through linen cloth in a funnel and washed with large volumes of boiling water until the solution was no longer basic. The residue was transferred into a crucible with water and then washed with

15ml alcohol. The crucible and its content was dried at 100ºC for one hour, cooled and weighed. The crucible with its content was then ignited in a muffle furnace pre-heated to 600°C for 30 minutes, cooled in a desiccator and re-weighed. The crude fibre was expressed as weight loss in weight percent.

### 3.3.6 Determination of Carbohydrate

Total carbohydrate was calculated by the difference between 100 and the sum of moisture, ash, crude fat, crude protein and crude fibre (Kirk and Sawyer, 1981).

### 3.3.7 Determination of Sugars

#### 3.3.7.1 Reducing Sugars

The Lane and Eynon (1990) method was used to determine the amount of reducing sugars present. Twenty (20) grams of samples was weighed and transfer into a 250 ml volumetric flask containing hot water. 5.0 ml of zinc acetate and potassium ferrocyanide solution was added.

Distilled water was added to the mark and allowed to stand for 10 minutes for clearing to take place. The sample was filtered and titrated against 10 ml of Fehling"s solution until brick red.

#### 3.3.7.2 Total Reducing Sugars (Invert Sugars)

Aliquot of the filtrate (from the procedure for reducing sugars above) was pipetted into a 100 ml volumetric flask and 10ml of HCl and invert/hydrolyzed in a water bath for 10 minutes at a temperature of 68 – 70°C. The sample was neutralize and titrated against 10 ml of Fehling"s solution. The sugar content was calculated as;

**CALCULATION**

$$\% \text{ Total reducing Sugar (invert sugar)} = \frac{\text{titre value} \times \text{amount of sample contained in volume}}{100}$$

### 3.3.8 Determination of Sucrose

Sucrose was determined by converting a portion of test solution with acid followed by neutralization with alkaline and titrated by the Lane-Eynon method using the standard invert sugar solution for calibration. The percentage sucrose was calculated as below;

% Sucrose = % invert sugar × 0.95

### 3.3.9 Determination of Total Sugars

The total sugar was determined as the additive value of the reducing sugars and the sucrose determined in 3.4.6 and 3.4.7 above.

### 3.3.10 Determination of Starch

The starch content was determined using (Pearson, 1990). The sample (2.5g) was put in a 100 ml volumetric flask and 25 ml of HCl introduced and shook to obtain proper distribution.

Hydrochloric acid (25 ml) was further added and the sample was immersed into boiling water bath. The sample was shook vigorously in the water bath for three minutes and left in the bath at boiling point for 15 minutes. The sample was removed and 30 ml of water was added and allowed to cool to 20°C. Five millilitres of carez1, 5 ml of carez II were added and shoo k for 1 min. The volume was then topped up to the mark and the sample was filtered. The test sample (5
g) was weighed into 100 ml volumetric flask and 40% ethanol was added and allowed to stand for 1 hour at room temperature. The sample was shook vigorously at six times intervals and the volume was topped up with ethanol and filtered. The sample (50 ml) was pipetted into 250 ml conical flask and 20 ml of HCl (7.6 M) was added and shook vigorously. The sample was then decanted into 100 ml volumetric flask and reflux for 15 mins. The sample was decanted into a 100 ml volumetric flask and clarified using carez 1 and II.

Calculation of results

$$\text{Percentage starch} = \frac{2000(p-p^1)}{[\alpha]^{20}}$$

P= total rotation in degrees $p^1$= rotation degrees given by the

substances in 40% ethanol

[ α ]= specific rotation of pure starch

## 3.4 SENSORY EVALUATION

### 3.4.1 Preparation of Sample for Sensory Evaluation

Yam tubers for the two cultivars were randomly selected at the end of the storage period. The middle portions of the selected tubers were cut, peeled, washed and cut into uniform pieces. Water was added to the sliced tubers and cooked for a period of 10min at 100$^{o}$C. Cooked slices were drained, wrapped in a cling film and put into food Ice chest to keep warm, until all the cultivars were ready for sensory evaluation. A freshly harvested yam tubers at nine months maturity of same cultivars as the stored samples were obtained from the farmer who supplied the stored ones. The tubers were passed through same process as the stored samples for evaluation.

### 3.4.2 Sensory Evaluation

Untrained assessors from Crop Research Institute (CRI) of Council for Scientific and Industrial Research (CSIR), Fumesua were selected based on previous involvement in sensory evaluation for affective test on yam varieties. The sensory attributes were explained to the understanding of the assessors. At evaluation session, each of the panelists received simultaneously samples of boiled yam and conducted independent assessments in separate sensory booths. Taste, hardness, mealiness, colour/appearance and overall acceptability were the sensory attributes considered. The levels of perception were assessed using a 9-hedonic scale, from 1 being like extremely to 9 being dislike extremely as shown in the questionnaire at appendix.

## 3.5 STATISTICAL ANALYSIS

All statistical Analyses were done using SPSS version 20 and GenStat software. The results obtained for each variety and barn type were compared using independent sample T-test and two-way Analysis of Variance (ANOVA). Significant differences in observed values were reported at 95% confidence interval.

# CHAPTER FOUR

## 4.0 RESULTS AND DISCUSSION

## 4.1 Temperature and Relative Humidity

The temperature and humidity profiles obtained over the period are shown in Figures 4.1 and 4.2 respectively.

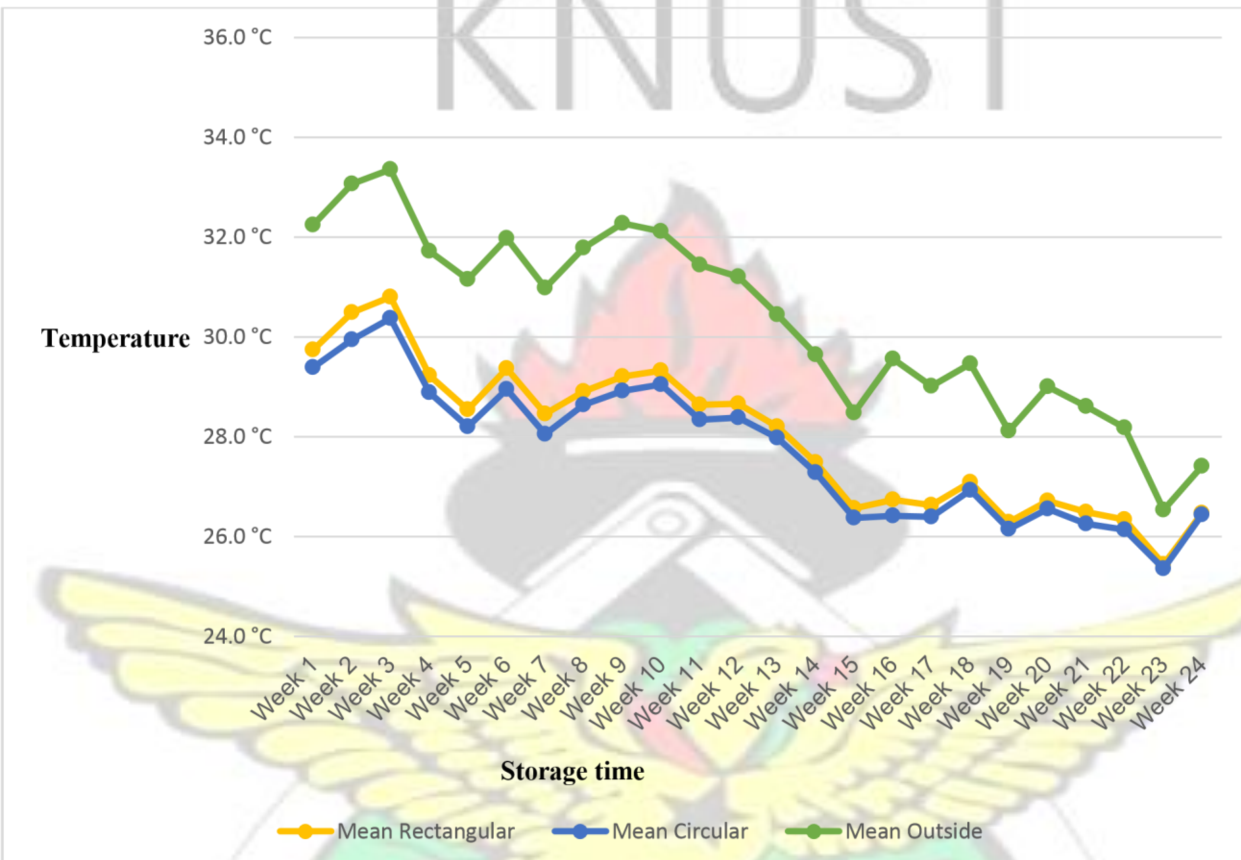



**Figure 4.1: Mean temperature of rectangular barn, circular barn and outside the barn**

**recorded over six months**

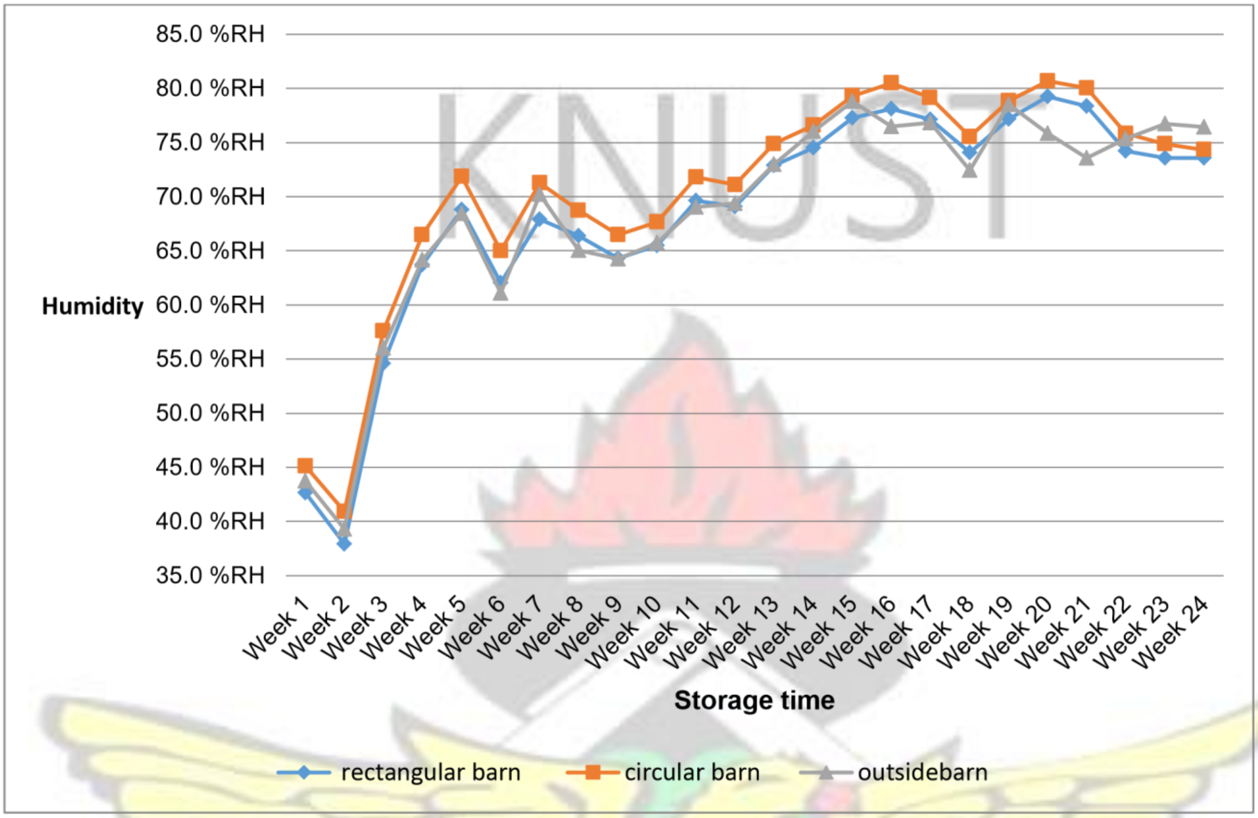



**Figure 4.2: Mean relative humidity of rectangular barn, circular barn and outside of barn recorded over six months**

Figures 4.2 and 4.3 show the temperature and relative humidity inside the rectangular barn, circular barn and outside the barns respectively. The data show that the temperature within the rectangular barn ranges between 25.4°C – 30.8°C while in the circular barn, the temperature ranges between 25.4°C – 30.4°C. The temperature outside the barn was between 26.5°C - 33.4°C. The temperature inside the barns was slightly lower than the temperature outside but the difference was not significant at 95% confidence interval ($p>0.05$). Lower temperatures are always preferable in barn storage of yams as it prevents weight loss and sprouting (Imeh *et al.*, 2012). Akinnusi *et al.* (1984) reported that, temperature between 15-20$^{o}$C can significantly reduce weight loss in stored yams.

This explains that the temperatures in the improved barns were higher than that suggested by (Imeh *et al*., 2012; Akinnusi *et al*. 1984) and as such could cause significant changes in weight loss. However, inside a traditional barn reported by (Mwinibalonno; 2015) a highest temperature of 39.6$^{o}$C was recorded while the highest temperature recorded inside the barns in this study was 30.8$^{o}$C. This shows that though the improved structures recorded temperatures higher than the recommended one for stored yams, it is better than traditional barn.

It was observed that the minimum temperature under all the three conditions was recorded on the 23$^{rd}$ week (which was in August) while the maximum temperature was recorded on the 3$^{rd}$ week (which fell on early March) This can be attributed to the relatively cold and hot weather conditions experienced in the country in August and March, 2015 respectively as it was reported by world weather and climate information that the Ashanti region of Ghana recorded a mean temperature of 24$^{o}$C in August and 34$^{o}$C in March (www.timeanddate.com).

Studies show that temperature and humidity are very important factors that affect the physiological characteristics of stored yam tubers and these changes in the physiological properties thereby affect the internal composition of the tuber and result in destruction of edible material, which when stored under normal storage conditions can often result in loss of tubers of up to 10% after 3 months, and up to 25% after 5 months of storage (Osunde and Orhevba, 2009). Comparing the temperature within the two barns, it was realized that the rectangular barn had slightly higher temperature and lower humidity than the circular barn though the difference was not statistically significant ($p>0.05$).

Observing the trend of the relative humidity for the three conditions as shown in Figure 4.2, it was realized that the minimum relative humidity was recorded on the second week for all the conditions. The rectangular barn recorded 37.9%, the circular barn recorded 40.9% while the humidity outside the barn was 39.3% as shown in figure 3. The maximum humidity for the circular and rectangular barn were 80.7% and 79.3% respectively compared to 61% in the barn with fan and 55% in the barn without fan of traditional storage reported by (Osunde and Orhevba, 2009). High humid environment leads to water retention hence an increase in the rate of rotting. This is emphasized by the high number of rots (65% for *pona* and *dente* in circular and 60% for both cultivars in rectangular) recorded in the study. However, there was no statistical difference ($p>0.05$) in the relative humidity recorded inside and outside the barns. Similar observation was made by (Kader, 2004) as it was reported that yams stored under such improved barns are exposed to uncontrollable environmental conditions like relative humidity.

## 4.2 Physical Properties

The field data collected provided information on the weight loss, tuber rot, sprout and rodent damage of the yam samples. Detailed observations made with regards to these parameters are discussed below.

### 4.2.1 Weight loss

The results obtained for the yam cultivars and effects of the barn types on the weight of the tubers are illustrated in Table 4.1.

**Table 4.1: Tuber Weight (kg) of the Different Yam Cultivars stored in Circular and Rectangular Barn types**

| | M0 | | M1 | | M2 | | M3 | | M4 | | M5 | | M6 | | Total Weight Loss (kg) | | Percentage Weight Loss | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cultivar** | **C** | **R** | **C** | **R** | **C** | **R** | **C** | **R** | **C** | **R** | **C** | **R** | **C** | **R** | **C** | **R** | **C** | **R** |
| ***Pona*** | 1.58 | 1.55 | 1.55 | 1.50 | 1.51 | 1.47 | 1.42 | 1.41 | 1.36 | 1.35 | 1.25 | 1.25 | 1.21 | 1.21 | **0.37** | **0.34** | **23.42** | **21.94** |
| ***Dente*** | 1.61 | 1.44 | 1.55 | 1.40 | 1.47 | 1.35 | 1.40 | 1.28 | 1.32 | 1.21 | 1.28 | 1.12 | 1.15 | 1.06 | **0.46** | **0.38** | **28.57** | **26.39** |

**KEY:** C-circular barn type, R-Rectangular barn type and M1-M6 represent Month 1 to Month 6 in that order. M0 is the initial month prior storage.

From Table 4.1, the weight of the yam tubers stored in both the circular and rectangular barns decreased significantly over the six months period (p=0.00) from 1.58kg to 1.21kg. This could be due to the temperature range recorded in the barns which were above 25°C. The increase in weight loss occurred as Maalekuu *et al*. (2014) reported that when tubers are kept for some time after harvest they begin to lose weight as a result of respiration due to constant high temperatures. Akinnusi *et al.* (1984) also reported that, temperatures within the range of 15°C to 20°C can significantly cause weight loss in stored yam. However, there was no significant difference in the tuber weights of yams stored under either types of barn (p-value=0.773). This purports that the barn types did not have any significant effect on the weight loss of tuber. This is in conformity with the findings of Mwinibalonno (2015) in which no significant interaction of barn structure was recorded on the weight loss of tubers.

From Table 4.1, there was no statistical difference ($p>0.05$) in weight loss recorded for both cultivars in the two barn types. However, there was slightly higher weight loss in both yam cultivars stored in the circular type of barns (*pona;* 23.42% and *dente*; 28.57%) as compared to the rectangular one (*pona;* 21.94% and *dente;* 26.39%) over the entire storage period. As reported by FAO (1998), improved air circulation often results in higher rate of water loss through transpiration. This explains the higher weight loss in the circular barns as it is associated with better circulation due to its design.

The results revealed that, weight loss of tubers stored in the improved barns is lower (ranging from 21.94 to 28.57%) as compared to tubers stored in traditional barns (32.8%) and on platforms (30.3%) as reported by Mijinyawa and Alaba (2013).

**TUBER ROT**

Table 4.2 shows the number of tuber rot recorded for each cultivar of yam stored in different barn types.

There was no significant difference (p-value of 0.865) in the number of tuber rot recorded for samples stored in the circular and rectangular barns though total mean rot in the rectangular barn was slightly higher (5.09) than the circular barn (4.64).

TABLE 4.2a: Effect of Barn type on tuber rot in stored yam varieties

| BARN TYPE | M0 | M1 | M2 | M3 | M4 | M5 | M6 | Total Mean Rot |
|---|---|---|---|---|---|---|---|---|
| **Circular** | 0 | 0.3 | 0.5 | 0.13 | 0.62 | 1.26 | 1.83 | **4.64** |
| **Rectangular** | 0 | 0.50 | 0.50 | 0.13 | 0.88 | 1.62 | 1.46 | **5.09** |

**Key**: **M1-M6** represents the first to the sixth month in that order; **C**-Circular barn type and **R**-Rectangular barn type. M0 is the initial prior storage

TABLE 4.2b: Number of Tuber Rot Recorded in Stored Yam Cultivars

| | M0 | M1 | | M2 | | M3 | | M4 | | M5 | | M6 | | Total Tuber Rot | | Percentage Tuber Rot | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cultivar** | | **C** | **R** | **C** | **R** | **C** | **R** | **C** | **R** | **C** | **R** | **C** | **R** | **C** | **R** | **C** | **R** |
| ***Pona*** | 0 | 3 | 2 | 4 | 3 | 1 | 1 | 6 | 7 | 1 | 13 | 14 | 3 | **29** | **29** | **48.33** | **48.33** |
| ***Dente*** | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 2 | 6 | 4 | **10** | **7** | **16.67** | **11.67** |

**Key**: **M1-M6** represents the first to the sixth month in that order; **C**-Circular barn type and **R**-Rectangular barn type. M0 is the initial prior storage.

Mwinibalonno (2015) recorded a mean number of rot of 1.2 in both circular and rectangular barns under different environmental conditions. In this study it was also observed that in both barn types, tuber loss due to rot increased appreciably in the $5^{th}$ and $6^{th}$ months. This indicates that the improved barns can store tubers better for about four months with minimal losses. Rot of over 60% in traditional storage system in Ghana has been reported by Aidoo (2011).

No significant rot was recorded for *dente* in the first four months but total rot of 10 tubers and 7 tubers were recorded for circular barn and rectangular barn respectively in the final two months. However, for the *pona* samples, tuber rot was observed in all the months with total rot of 29 tubers in each of circular and rectangular barn, suggesting availability of unfavourable storage condition and susceptibility of *pona* cultivar to rot bacteria. This suggests that the *Dente* yam samples may have a longer shelf life under these storage conditions than the *pona*. This is in concordance with the work of (Asare-Bediako *et al.* 2007a) in which it was reported that, *pona* is often heavily infected by rot-causing microorganisms such as *Aspergillus flavus* compared to *dente*. Mwinibalonno, (2015) and other research works have also attributed the high rot in *pona* to its high sugar content which makes it more susceptible to bacteria infestations.

**TUBER SPROUT**

The occurrence of sprout of the yam samples as shown in Table 4.3 indicated that both storage facilities had favourable conditions for sprouting of the yam sample. For the entire period of storage, sprouting was observed in yam tubers stored in both the circular and rectangular barn.

**Table 4.3a: Effect of Barn Type on Tuber Sprout in Stored Yams**

| BARN TYPE | NUMBER OF SPROUTED TUBERS | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | MONTHS | | | | | | | Total Mean Sprout |
| | **M0** | **M1** | **M2** | **M3** | **M4** | **M5** | **M6** | |
| **Circular** | 0 | 5.50 | 7.12 | 7.38 | 8.50 | 2.09 | 1.58 | **32.17** |
| **Rectangular** | 0 | 7.38 | 7.62 | 7.75 | 7.12 | 2.14 | 1.09 | **33.1** |

**Key**: **M1-M6** represents the first to the sixth month in that order; **C**-Circular barn type and **R**-Rectangular barn type. M0 is the initial prior storage.

**TABLE 4.3b: Number of Tuber Sprout Recorded in Stored Yam Cultivars**

| | **M0** | **M1** | | **M2** | | **M3** | | **M4** | | **M5** | | **M6** | | **Total Sprouted Tubers** | | **Percentage Sprouted Tubers** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cultivar** | | **C** | **R** | **C** | **R** | **C** | **R** | **C** | **R** | **C** | **R** | **C** | **R** | **C** | **R** | **C** | **R** |
| ***Pona*** | 0 | 17 | 27 | 22 | 22 | 28 | 29 | 30 | 25 | 4 | 6 | 0 | 0 | **101** | **109** | **38.85** | **38.38** |
| ***Dente*** | 0 | 27 | 32 | 35 | 35 | 31 | 32 | 38 | 32 | 26 | 28 | 15 | 3 | **172** | **162** | **51.19** | **46.96** |

**Key**: **M1-M6** represents the first to the sixth month in that order; **C**-Circular barn type and **R**-Rectangular barn type. M0 is the initial prior storage

Total mean sprouting in rectangular barn (32.17) was slightly higher than that in the circular barn (33.10). However, the difference in sprout recorded in both barn types was insignificant at 95% confidence interval (p=0.930). The marginal increase in sprouting in the rectangular barn could be attributed to the slightly higher, though insignificant, temperature recorded in the rectangular barn as showed in table 4.3. Mwinibalonno, (2015) also recorded no significant difference in sprout formation for tubers stored in circular (4.6) and rectangular barns (4.5).Therefore, the high temperatures in the barns may not be ideal for sprout control. Imeh *et al*. (2012) established that, only storage at 15$^{o}$C can effectively suppress sprouting in yams for six months.

From table 4.3b it can be observed that, in the circular barn, the percentage of sprout formation in *dente* was significantly higher (51.19% in circular barn) and (46.96% in rectangular barn) compared to *pona* (38.85% in circular barn) and (38.38% in rectangular barn). These findings are comparable to that of Mwinibalonno, (2015) which also recorded significantly lower frequency of sprouting in *pona* variety over a four-month period in an improved storage barn. AsareBediako *et al*. (2007b) also recorded higher mean percentage sprouting in *dente* minisetts as compared to *pona*. Highest tuber sprout was observed in the third and fourth months for *pona* and *dente* respectively. However, Sprouting decreased appreciably after the 5$^{th}$ and 6$^{th}$ months of storage for both varieties. This could be attributed to the significant loss of water and dry matter approaching the latter stages of storage.

Comparison of the performance of improved barn in this study to a traditional barn reported by (Maalekuu *et al*. 2014), shows that sprout formation in the improved barns was lower (38,3838.85% for *pona* and 46.96-51.19% for *dente)* than the traditional barn (53.33% for *Pona* and

93.33% for *Tela).* This means the improved barns can cause some reduction in tuber loss due to sprouting.

**RODENT DAMAGE**

The new improved barns were designed using wooden poles and guards to prevent rodent infestation and subsequent damage of the stored yams. The efficiency of the barn types in preventing rodent entry was investigated by recording rodent damage to the tubers (if any) over the storage period. The observation made in terms of the damage in the two barn types and on the yam varieties are illustrated in Table 4.4.

**Table 4.4: Rodent Damage observed in the Two Barn types and Yam Cultivars**

| BARN TYPE | RODENT DAMAGE MONTHS | | | | | | | Total Mean Rodent Damage |
|---|---|---|---|---|---|---|---|---|
| | **M0** | **M1** | **M2** | **M3** | **M4** | **M5** | **M6** | |
| **Circular** | 0 | 0.00 | 0.00 | 0.00 | 1.38 | 1.34 | 1.05 | **3.77** |
| **Rectangular** | 0 | 0.00 | 0.00 | 0.38 | 0.62 | 1.60 | 1.39 | **3.99** |

**Key**: **M1-M6** represents the first to the sixth month in that order; **C**-Circular barn type and **R**-Rectangular barn type. **M0** is the initial prior storage

**TABLE 4.4b: Number of Rodent Damage Recorded in Stored Yam Cultivars**

| | M0 | M1 | | M2 | | M3 | | M4 | | M5 | | M6 | | Total Rodent Damage | | Percentage Rodent damage | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cultivar** | | **C** | **R** | **C** | **R** | **C** | **R** | **C** | **R** | **C** | **R** | **C** | **R** | **C** | **R** | **C** | **R** |
| ***Pona*** | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 12 | 4 | 4 | 12 | 6 | 8 | **22** | **26** | **8.50** | **9.20** |
| ***Dente*** | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 2 | 4 | 2 | 4 | 1 | **11** | **6** | **3.30** | **1.70** |

**Key**: **M1-M6** represents the first to the sixth month in that order; **C**-Circular barn type and **R**-Rectangular barn type. **M0** is the initial prior storage

From table 4.4, a total mean rodent damage of 3.77 and 3.99 were recorded in the circular and rectangular barns respectively. The rodent damage was observed after the second month in the rectangular barn and after the third month in the circular barn. There was no significant difference ($p=0.929$) in the rodent damage observed for the two barn types. This shows that the barns were efficient in rodent control in the first and second months of storage but was not so in subsequent months. This was attributed to shrinkage of erected wooden poles due to water loss which created openings between the poles and the rodent guards facilitating rodents‟ access to the stored yam.

Rodent damage occurred mostly in the *pona* cultivar (17.7%) compared to the *dente* (5%). The high rodent damage in *pona* may probably be due to the comparatively high sugar content (sweet nature) of that cultivar (6.2g/100g) from Table 4.5.

### 4.3 Chemical Properties

Chemical properties of the fresh and stored yam cultivars as shown in table 4.5 revealed that, *Dente* had significantly higher initial moisture content (62.3 %) compared to *pona* variety (58.6 %). The moisture content obtained for each variety was within the range for amount of moisture in fresh yam (50-80% wet basis) reported by (Oyelade *et al.* 2008; Addy, 2012). Otegbayo *et al*. (2012) also recorded moisture content of *D. rotundata* in the range of 62.14-69.12%. The moisture content obtained for *dente* in this study was within these ranges but that of *pona* was slightly below the range.

**Table 4.5: Chemical properties of yam cultivars stored in two barn types for six months**

| Chemical property (g/100g) | Yam variety | Initial | Third Month RB | Third Month CB | Sixth month RB | Sixth month CB |
|---|---|---|---|---|---|---|
| **Moisture** | *Dente* | 62.3±0.02 $^{a*}$ | 56.00±0.20$^{b*}$ | 57.2±0.100$^{ab*}$ | 48.1±0.195$^{c*}$ | 49.9±0.045$^{c*}$ |
| | *pona* | 58.6±0.020$^{a**}$ | 54.80±0.070$^{b*}$ | 55.2±0.100$^{b*}$ | 51.1±0.085$^{c*}$ | 50.4±0.040$^{c*}$ |
| **Ash** | *Dente* | 1.26±0.040$^{a*}$ | 1.52±0.020$^{a}$ | 1.13±0.010a | 1.41±.000a | 1.12±0.060a |
| | *Pona* | 1.03±0.010$^{a*}$ | 0.92±0.005$^{a}$ | 0.79±0.010a | 1.01±0.015a | 0.68±0.010a |
| **Fat** | *dente* | 0.80±0.035 $^{a*}$ | 0.17±0.001 $^{a*}$ | 0.51±0.010 $^{a*}$ | 0.15±0.005$^{a*}$ | 0.3±0.005 $^{a*}$ |
| | *pona* | 0.70±0.09 $^{a*}$ | 0.71±0.010 $^{a*}$ | 1.33±0.010 $^{a*}$ | 0.09±0.005 $^{a*}$ | 0.11±0.020$^{a*}$ |
| **Protein** | *dente* | 3.46±0.022$^{ab*}$ | 6.30±0.10$^{c}$ | 5.95±0.010$^{bc}$ | 2.85±0.035$^{a}$ | 1.21±0.050 $^{a}$ |
| | *pona* | 2.31±0.118$^{b*}$ | 4.82±0.010$^{ab}$ | 6.13±0.010$^{a}$ | 3.17±0.06$^{b}$ | 2.69±0.040$^{b}$ |
| **Carbohydrate** | *Dente* | 32.18±0.020 $^{a}$ | 28.42±0.010$^{b}$ | 27.00±0.200$^{b}$ | 22.4±0.35$^{c}$ | 23.81±0.305$^{c}$ |
| | *Pona* | 37.36±0.198$^{a}$ | 29.66±0.010$^{b}$ | 30.07±0.110$^{b}$ | 24.33±0.01$^{c}$ | 23.18±0.185$^{d}$ |
| **Fibre** | *Dente* | 4.30±0.050 | 3.79±0.020 | 3.81±0.010 | 1.08±0.11 | 1.21±0.245 |
| | *Pona* | 3.20±0.020 | 2.09±0.010 | 1.48±0.020 | 2±0.14 | 0.3±0.075 |
| **Reducing Sugar** | *Dente* | 0.83±0.010$^{a}$ | 0.94±0.010$^{a}$ | 0.98±0.020$^{a}$ | 1.16±0.00$^{a}$ | 1.18±0.00$^{a}$ |
| | *Pona* | 0.30±0.020$^{a}$ | 0.42±0.010$^{ab}$ | 0.43±0.00$^{ab}$ | 0.6±0.010$^{b}$ | 1.2±0.050$^{c}$ |

| Chemical property (g/100g) | Yam variety | Initial | Third Month RB | Third Month CB | Sixth Month RB | Sixth Month CB |
|---|---|---|---|---|---|---|
| Sucrose | *Dente* | 1.06±0.005[a] | 2.04±0.010[ab] | 2.95±0.02[bc] | 3.7±0.10[c] | 3.8±0.10[c] |
| | *Pona* | 1.32±0.010[a] | 2.12±0.010[a] | 2.01±0.00[a] | 5.6±0.10[b] | 3.2±0.050[c] |
| Total Sugar | *Dente* | 3.21±0.010[a] | 3.80±0.050[a] | 3.87±0.01[a] | 4.3±0.10[a] | 4. 5±0.10[a] |
| | *Pona* | 3.91±0.010[a] | 4.71±0.010[a] | 4.64±0.01[a] | 6.2±0.10[a] | 5.93±0.00[a] |
| Starch | *Dente* | 48.9±0.030[a] | 41.5±0.060[b] | 41.20±0.10[b] | 34.2±0.00[c] | 34±0.00[c] |
| | *Pona* | 53.7±0.020[a] | 46.10±0.10[b] | 46.90±0.15[b] | 33.3±0.10[c] | 34.1±0.00[c] |

**Key: RB**-Rectangular Barn, **CB**-Circular Barn. Mean values with at least one similar letter (superscript) row wise are significant at 95%confidence level. Those with entirely different letters are not significant at 95% confidence level. Mean values with same number of * in a column are not significantly different at 95% confidence interval.

After three months of storage, both varieties had decreased appreciably in moisture content though the decrease in moisture content in the *dente* variety was not significant ($p<0.05$) at 95% confidence interval. Six months of storage proved to reduce moisture content significantly in both cultivars. It was also observed that, the different barn types did not have any significant effect on the rate of moisture loss in the *pona* variety but the *dente* variety stored in rectangular barn showed significant reduction in moisture content after the third month but significant reduction of moisture in circular barn was not observed in the first three months. The loss of moisture in these improved barns is comparable to that obtained in traditional barns as reported by (Maalekuu *et al.* 2014). However, the environmental conditions which might be different in both studies cannot be overlooked. The occurrence of moisture loss in yams under storage is mostly due to respiration, transpiration and sprouting of the tubers, (Otegbayo *et al*., 2012).

This study also reported on the ash, protein, fat, fibre, carbohydrate, total sugar, sucrose, energy and starch content of the two yam varieties (Table 4.5). The ash content which represents the amount of minerals in the sample was found to be 1.26 g/100g in the fresh *dente s*ample and 1.03 g/100g in the fresh *pona* sample. The initial ash content in both varieties were not statistically different ($p>0.05$). These values conforms with study by Osagie (1992) as they reported ash content in fresh yam as ranging from 0.6 – 1.7 g/100g. As the period of the storage extended, it was observed that the ash content decreased as well but the decrement was not statistically different. This purports that the ash content in the stored yams was fairly maintained over the storage period. Ravi *et al*. (1996) observed a decrease in the ash content after 150 days of storage. They reported that various chemical changes occur in yam tubers during storage which may affect the ash content. Further observation showed that samples in the rectangular barn recorded higher ash content than those in the circular barn though the difference was not significant.

In terms of fat content, there was no significant difference ($p=0.89$) between fresh *dente* yam (0.8 g/100g) and the *pona* yam sample (0.7 g/100g). According to Frank and Kingsley (2014), the fat content of yam is between the range of 0.39 g/100g – 1.67 g/100g which is consistent with the result obtained from this study. The storage period did not affect the fat content significantly for the *dente* variety ($p>0.05$), even though slight decrease in the content was observed at the end of the storage period. No significant difference ($p>0.05$) was obtained for fat content of yams stored in the different barn types. Maalekuu *et al*. (2014) also recorded a decrease in fat content in white yam stored in three different traditional barns for a period of five months.

The protein analysis of the two yam samples as shown in the table indicated crude protein content of 3.46 and 2.31g/100g in the fresh *dente a*nd *pona* samples respectively. Addy (2012) reported that the protein content of fresh samples of *D. rotundata* ranges from 0.087 – 4.3 g/100g but the protein content is liable to decrease after some period of storage. However, after three months of storage, there was an increase in protein content in both cultivars and the difference was significant in the circular and rectangular barns for *pona* and *dente* respectively. This suggests that, the rectangular barn type may be a better storage option for the *dente* sample while the circular barn may be ideal for the *pona* variety for the first three months of storage. Ravi *et al*., (1996) also observed an increase in protein content of *D. rotundata* samples under storage. However, by the end of the six months of storage, the protein content in both varieties decreased significantly in either barn types. The reduction in protein may be due to proteic synthesis or a weak proteolysis that could be initiated by proteases as suggested by (Kumar and Kwnols, 1993a). Trèche and Agbor-Egbe, (1996) did not observe any significant changes in *Discorea sp.* stored in conventional traditional barns up to 4 months.

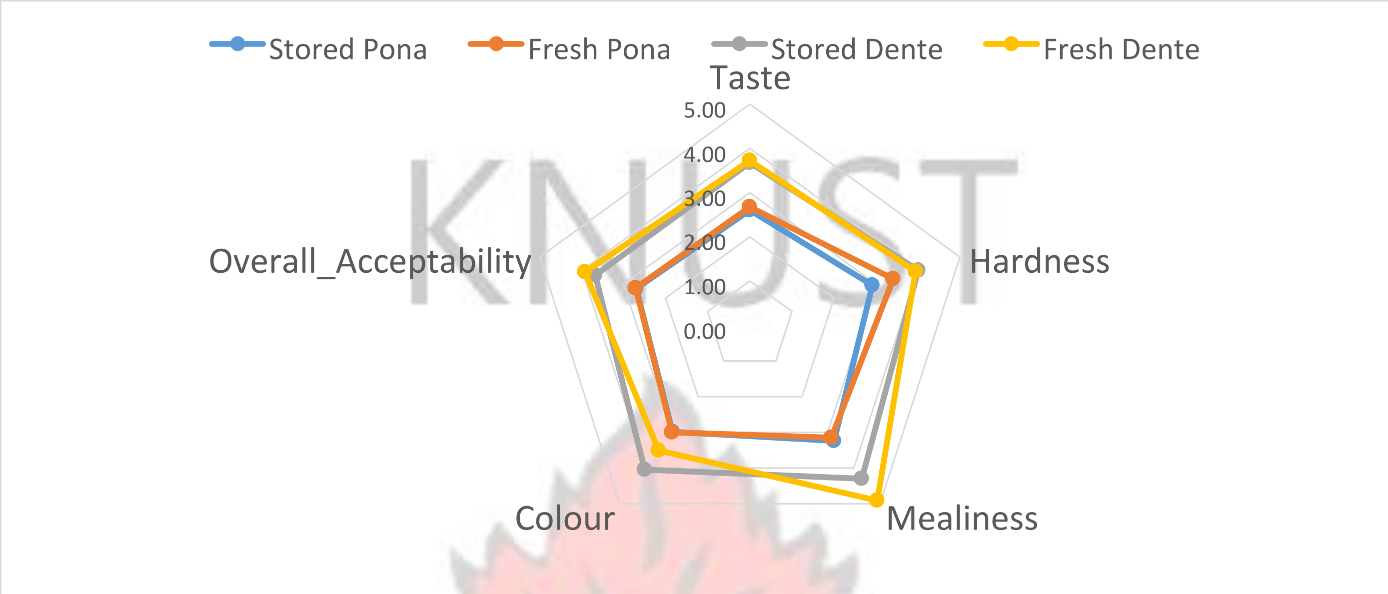
Carbohydrate which is known to be the major nutrient of yam was found to be 32.18 g/100g in the fresh *dente* samples and 37.36 g/100g in the fresh *pona* samples. Addy (2012) reported a range of 15 – 40.61 g/100g for *D. rotundata* which is in agreement with the results as obtained in this study. As illustrated in the table, the carbohydrate content of both yam samples in either barn types decreased significantly throughout the storage period. This observation is consistent with the findings of (Osunde and Orhevba, 2009). They recorded a decrease in carbohydrate content from 24.6 g/100g to 22.05 g/100g by the end of six months of storage. This loss in carbohydrate content of stored tubers is due to respiration and transpiration (conversion of CHO to oxygen and water) as well as sprouting often resulting from high temperatures. The barn difference did not have any significant influence on the carbohydrate content of the yams after three months of storage but after six months, *pona* variety in the rectangular barn showed significantly higher carbohydrate content (24.3 g/100g) than in the circular barn (23.18 g/100g)).

There was no significant change ($p>0.05$) observed in the total sugar content present in both yam samples over the period of storage. The fresh *dente* sample recorded total sugar level of 3.2 g/100g but increased marginally to 4.5 g/100g after the sixth month of storage, for the fresh *pona* samples, the total sugar before storage was observed to be 3.91 g/100g but increased to 5.9 and 6.2 g/100g after six months of storage in the circular and rectangular barns respectively. Dje *et al.* (2010) also observed an increase in the total sugar content of yam samples after storage. Ravi *et al*. (1996), in their studies, also observed an increase in the total sugar present in yam after four months of storage. Reducing sugar and sucrose level also increased in stored samples in this study. The increase in sugar might be as a result of the breakdown and hydrolysis of starch into sugars during storage. This agrees with studies by (Ravi *et al.*, 1996; Dje *et al.*, 2010). The increment in reducing sugar was only significant in the 6th month for *pona* in circular barns but for the *dente* variety, it was not significant over the entire storage period and in either barn types.

Contrary to increase in sugar content, the level of starch present in yam samples declined significantly ($p<0.05$) as the storage period extended. As presented in table 4.5, the starch content of the *Dente* yam samples was found to be 48.9 g/100g but reduced to 34 g/100g after the sixth month of storage. The *pona* yam samples also recorded starch content of 53.7 but reduced to 33.3 g/100g and 34.1g/100g in the rectangular and circular barns respectively. The reduction in starch content of yam has also been reported by (Ravi *et al*., 1996). The reduction as observed can be attributed to the post-harvest breakdown of starch and subsequent hydrolysis to sugars (Otegbayo *et al*., 2012). Samples stored in different barn types did not show any significant difference in their total sugar, sucrose and starch contents. However, a significant increase in these parameters were observed in conventional barns in the work done by (Afoakwa and Sefa-Dedeh, 2001).

**4.4 Sensory Evaluation**

The results from the sensory evaluation on the boiled yam prepared from the two cultivars of *Dioscorea rotundata (dente and pona*) showed that, in terms of taste, the stored *pona* and fresh *pona* were both liked very much compared to the *dente* which was moderately preferred.




Scale: **1**-Like Extremely **2**-Like Very Much **3**-Like Moderately **4**-Like Slightly **5**-Neither Like nor Dislike **6**-Dislike Slightly **7**-Dislike Moderately **8**-Dislike Very Much **9**-Dislike Extremely

**Figure 4.3: Sensory evaluation of fresh and stored yam samples (six months storage)**

The preference of the *pona* over the *dente* is as a result of its comparatively high total sugar level (as emphasized in table 4.5) hence improving the taste, as reported by (Wireko-Manu *et al.*, 2013). There was no significant difference between the taste preference recorded for stored and fresh samples (both *pona* and *dente*). Tortoe *et al*. (2014) also explained that, despite the two cultivars belonging to the same variety (*Dioscorea rotundata*), intrinsic properties that control the breakdown of starches into sugars at storage and other related mechanisms concerning sugar content vary. Baah (2009) reported that *pona* cultivar is generally mostly preferred in terms of taste as compared to other *D. rotundata* cultivars. Otegbayo *et al*. (2001) also reported that boiled yam from *pona*, a cultivar of *D. rotundata* is rated superior to other cultivars in terms of its cooking quality attributes.

Mealiness, hardness, stickiness, sogginess and waxiness describe texture attribute of boiled yam (Otegbayo *et al*, 2005). In this study, textural attributes considered were hardness and mealiness. As shown in Figure 4.3, the stored *pona* was much preferred than the fresh *pona* in terms of hardness. For the *dente* samples, the fresh *dente* was moderately preferred over the stored *dente*. In the case of mealiness, *pona* (either fresh or stored) was more preferred (liked moderately) to the stored and fresh *dente* (liked slightly). That notwithstanding, between the fresh and stored dente, the stored dente was marginally preferable. The differences in texture between the two cultivars (*pona* and *dente*) suggests different histological properties among the two and further reveals the likelihood of dissimilar breakdown or loss of cellular integrity and other chemical properties during cooking (Tortoe *et al*., 2014). Wireko-Manu *et al.* (2013) also showed that, increase in dry matter, sugar content, swelling and pasting properties can significantly improve the organoleptic and textural properties of tubers.

In terms of the colour acceptability, stored *pona* was liked very much as against the fresh *pona* which was liked moderately as shown in Figure 4.3. The *pona* again was highly preferred over *dente* even though stored *dente* was least preferred (liked slightly). Though it has been reported that *D.alata* is prone to browning than *D. rotundata,* (Baah, 2009), between the two *D. rotundata* cultivars used in this study it was realized during the preparation stage that *dente* was more prone to browning than *pona.* This could account for the colour of *pona* being more acceptable than that of the *dente.* It is also in concordance with the findings of Tortoe *et al*. (2014), that the colour of boiled *pona* is significantly preferred than *dente*.

Results from the overall acceptability of the samples indicated that the *pona* was overall acceptable as compared to the *dente*. No significant difference in acceptability was observed between the stored and fresh samples even though the stored samples were slightly preferred over the fresh ones. Considering the two cultivars, *pona* was scored high in all the attributes and there was significant difference between it and *dente.*

# CHAPTER FIVE

## 5.0 CONCLUSION AND RECOMMENDATIONS

### 5.1 Conclusion

1. Temperature and relative humidity inside the improved barns (circular and rectangular) were not significantly different from each other. Temperatures recorded in the improved

barns were relatively lower than that reported in traditional storage barns. For relative humidity, the improved barns recorded higher percentages than what has been reported in traditional storage barns.

2. Generally, the improved structures had significant impact on the physical, chemical and sensory properties of the stored yams.

    I. There was no significant difference observed in the physical conditions in both barn types and as such they did not appear to have any differential effect on the properties of the stored yam cultivars. Physical properties of the stored tubers deteriorated during storage especially after four months of storage. Tuber rot was higher in *pona* but *dente* had more sprouts. Rodent damage which occurred after three months of storage was prominent in *pona* (17%) as compared to dente (5%)

    II. There was significant decrease in carbohydrate content during storage but no consistent variations in the protein content during storage. Ash and fat content did not change significantly during storage ($p>0.05$). The sugar content (sucrose, total sugars and reducing sugars) increased as the starch content of the tubers decreased at storage. Storage period affected most chemical properties but the different barn types showed no significant effect on these properties.

    III. Storage seemed to have improved the sensory properties as stored boiled yams were more preferred the most during the sensory evaluation. Yam tubers could be stored in the improved barn for four months with fewer losses compared to traditional bans as reported in the literature

## 5.2 Recommendations

1. Further studies should be conducted on improving the ventilation of the storage structures in order to minimize the rate of sample rot.
2. Studies should also be conducted on the functional properties of the stored yam.
3. Chemical analysis should be done on stored samples at the end of each month of storage in order to determine more appropriately when the stored yam begins to deteriorate.
4. The rectangular barn is recommended to be used for storage of yam tubers.

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## APPENDIX I

**Table 1: A 9-hedonic scale showing levels of perception**

**Sensory evaluation of two varieties of boiled yam**

Name…………………………………………….........................

Date…………………

You are presented with four (4) samples of boiled yam, kindly take a bite as taught and assess the samples based on your degree of likeness for the different quality attributes using the scale below “like extremely to dislike extremely”. Evaluate each sample in the order presented. Please wash your mouth with water after biting each sample.

1. Like Extremely
2. Like Very Much
3. Like Moderately
4. Like Slightly
5. Neither Like nor Dislike

6. Dislike Slightly
7. Dislike Moderately
8. Dislike Very Much
9. Dislike Extremely

| Sample Code | Taste | Hardness | Mealiness | Colour / Appearance | Overall Acceptability |
|---|---|---|---|---|---|
| 110 | | | | | |
| 196 | | | | | |
| 127 | | | | | |
| 115 | | | | | |

Comments

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**APPENDIX II**

Statistical Comparison of Temperature Inside And Outside Barns

**Temperature** Tukey HSD

| VAR00002 | N | Subset for alpha = 0.05 | |
|---|---|---|---|
| | | 1 | 2 |
| Circular | 24 | 194.0542 | |
| Rectangular | 24 | 195.9292 | |
| Outside | 24 | | 212.2458 |
| Sig. | | .832 | 1.000 |

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 24.000.

**Statistical Comparison of Humidity In And Outside Barns**

**Humidity** Tukey HSD

| VAR00002 | N | Subset for alpha = 0.05 |
|---|---|---|
| | | 1 |
| Outside | 24 | 461.0458 |
| Rectangular Ban | 24 | 479.1208 |
| Circular Barn | 24 | 494.2458 |
| Sig. | | .385 |

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 24.000.

**Comparison of weight loss in tubers in circular barns**

**Descriptives**

VAR00004

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| M1 | 3 | 21.6000 | .02000 | .01155 | 21.5503 | 21.6497 | 21.58 | 21.62 |
| M2 | 3 | 13.2800 | .02000 | .01155 | 13.2303 | 13.3297 | 13.26 | 13.30 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| M3 | 3 | 11.9000 | .02000 | .01155 | 11.8503 | 11.9497 | 11.88 | 11.92 |
| M4 | 3 | 10.9467 | .02517 | .01453 | 10.8842 | 11.0092 | 10.92 | 10.97 |
| M5 | 3 | 2.8600 | .02000 | .01155 | 2.8103 | 2.9097 | 2.84 | 2.88 |
| M6 | 3 | 2.3200 | .02000 | .01155 | 2.2703 | 2.3697 | 2.30 | 2.34 |
| Total | 18 | 10.4844 | 6.75252 | 1.59158 | 7.1265 | 13.8424 | 2.30 | 21.62 |

**ANOVA**

VAR00004

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 775.135 | 5 | 155.027 | 353226.248 | .000 |
| Within Groups | .005 | 12 | .000 | | |
| Total | 775.141 | 17 | | | |

**Comparison of weight loss of tuber in rectangular barn over six months period**

**Descriptives**

VAR00004

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| M1 | 3 | 20.3600 | .02000 | .01155 | 20.3103 | 20.4097 | 20.34 | 20.38 |
| M2 | 3 | 11.6400 | .02000 | .01155 | 11.5903 | 11.6897 | 11.62 | 11.66 |
| M3 | 3 | 10.3500 | .02000 | .01155 | 10.3003 | 10.3997 | 10.33 | 10.37 |
| M4 | 3 | 8.6800 | .02000 | .01155 | 8.6303 | 8.7297 | 8.66 | 8.70 |
| M5 | 3 | 2.5500 | .02000 | .01155 | 2.5003 | 2.5997 | 2.53 | 2.57 |
| M6 | 3 | 2.1700 | .02000 | .01155 | 2.1203 | 2.2197 | 2.15 | 2.19 |
| Total | 18 | 9.2917 | 6.31087 | 1.48749 | 6.1533 | 12.4300 | 2.15 | 20.38 |

VAR00004

| Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|
| .000 | 5 | 12 | 1.000 |

**ANOVA**

VAR00004

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 677.055 | 5 | 135.411 | 338527.625 | .000 |

| | | | | | |
|---|---|---|---|---|---|
| Within Groups | .005 | 12 | .000 | | |
| Total | 677.060 | 17 | | | |



**APPENDIX III**

**Analysis of variance**

Variate: M1_TW

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| REPLICATIONS stratum | 3 | 2.5219 | 0.8406 | 0.87 | |
| REPLICATIONS.*Units* stratum | | | | | |
| BARN | 1 | 6.1256 | 6.1256 | 6.30 | 0.033 |
| VARIETY | 1 | 0.1806 | 0.1806 | 0.19 | 0.677 |

| | | | | | |
|---|---|---|---|---|---|
| BARN.VARIETY | 1 | 4.7306 | 4.7306 | 4.87 | 0.055 |
| Residual | 9 | 8.7456 | 0.9717 | | |
| Total | 15 | 22.3044 | | | |

*Message: the following units have large residuals.*

REPLICATIONS 4 *units* 2   1.71 s.e.   0.74

**Tables of means**

Variate: M1_TW

Grand mean  20.98

| BARN | Circular | Rectangular |
|---|---|---|
| | 21.60 | 20.36 |

| VARIETY | Denteh | Pona |
|---|---|---|
| | 21.09 | 20.88 |

BARNVARIETY      Denteh        Pona

| | | |
|---|---|---|
| Circular | 22.25 | 20.95 |
| Rectangular | 19.93 | 20.80 |

**Standard errors of means**

Table BARN VARIETY BARN

VARIETY

rep. 8 8 4 d.f. 9 9 9

e.s.e. 0.349 0.349 0.493

**Standard errors of differences of means**

Table BARN VARIETY BARN

VARIETY

rep. 8 8 4 d.f. 9 9 9

s.e.d. 0.493 0.493 0.697

**Least significant differences of means (5% level)**

Table BARN VARIETY BARN

VARIETY rep. 8 8 4 d.f. 9

9 9

l.s.d. 1.115 1.115 1.577

**Stratum standard errors and coefficients of variation**

Variate: M1_TW

| Stratum | d.f. | s.e. | cv% |
|---|---|---|---|
| REPLICATIONS | 3 | 0.458 | 2.2 |
| REPLICATIONS.*Units* | 9 | 0.986 | 4.7 |

Analysis of variance

Variate: M1_TR

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| REPLICATIONS stratum | 3 | 0.1875 | 0.0625 | 0.27 | |
| REPLICATIONS.*Units* stratum | | | | | |
| BARN | 1 | 0.0625 | 0.0625 | 0.27 | 0.614 |
| VARIETY | 1 | 1.5625 | 1.5625 | 6.82 | 0.028 |
| BARN.VARIETY | 1 | 0.0625 | 0.0625 | 0.27 | 0.614 |
| Residual | 9 | 2.0625 | 0.2292 | | |

Total 15 3.9375

*Message: the following units have large residuals.*

REPLICATIONS 1 *units* 1 -0.8s.e. 0.36

**Tables of means**

Variate: M1_TR

Grand mean 0.44

| BARN | Circular | Rectangular |
|---|---|---|
| | 0.38 | 0.50 |

| VARIETY | Denteh | Pona |
|---|---|---|
| | 0.00 | 0.75 |

| BARN VARIETY | Denteh | Pona |
|---|---|---|
| Circular | 0.00 | 0.75 |
| Rectangular | 0.25 | 0.75 |

**Standard errors of means**

| Table | BARN | VARIETY | BARN VARIETY |
|---|---|---|---|
| rep. | 8 | 8 | 4 |
| d.f. | 9 | 9 | 9 |
| e.s.e. | 0.169 | 0.169 | 0.239 |

**Standard errors of differences of means**

| Table | | | | BARN | VARIETY | BARN VARIETY |
|---|---|---|---|---|---|---|
| rep. | 8 | 8 | 4 | | | |
| d.f. | | | | 9 | 9 | 9 |
| s.e.d. | | | | 0.239 | 0.239 | 0.339 |

**Least significant differences of means (5% level)**

| Table | | | | BARN | VARIETY | BARN VARIETY |
|---|---|---|---|---|---|---|
| rep. | 8 | 8 | 4 | | | |
| d.f. | | | | 9 | 9 | 9 |
| l.s.d. | | | | 0.541 | 0.541 | 0.766 |

**Stratum standard errors and coefficients of variation**

Variate: M1_TR

| Stratum | d.f. | s.e. | cv% |
|---|---|---|---|
| REPLICATIONS | 3 | 0.125 | 28.6 |

| | | | |
|---|---|---|---|
| REPLICATIONS.*Units* | 9 | 0.479 | 109.4 |

**Analysis of variance**

Variate: M1_RD

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

**Tables of means**

Variate: M1_RD

Grand mean 0.00

| BARN | Circular | Rectangular |
|---|---|---|

| | |
|---|---|
| 0.00 | 0.00 |

| VARIETY | Denteh | Pona |
|---|---|---|
| | 0.00 | 0.00 |

| BARN | VARIETY | Denteh | Pona |
|---|---|---|---|
| Circular | | 0.00 | 0.00 |
| Rectangular | | 0.00 | 0.00 |

Standard errors of means

| Table | BARN | VARIETY | BARN VARIETY |
|---|---|---|---|
| rep. | 8 | 8 | 4 |
| d.f. | * | * | * |
| e.s.e. | 0.000 | 0.000 | 0.000 |

**Standard errors of differences of means**

| Table | BARN | VARIETY | BARN VARIETY |
|---|---|---|---|
| rep. | 8 | 8 | 4 |
| d.f. | * | * | * |
| s.e.d. | 0.000 | 0.000 | 0.000 |

**Least significant differences of means (5% level)**

| Table | BARN | VARIETY | BARN VARIETY |
|---|---|---|---|
| rep. 8 8 4 | d.f. | * | * | *
| l.s.d. | * | * | * |

**Stratum standard errors and coefficients of variation**

Variate: M1_RD

| Stratum | d.f. | s.e. | cv% |
|---|---|---|---|
| REPLICATIONS | 3 | 0.000 | 0.0 |
| REPLICATIONS.*Units* | 9 | 0.000 | 0.0 |