KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,

KUMASI

COLLEGE OF EGINEERING

DEPARTMENT OF AGRICULTURAL EGINEERING

PERFORMANCE OF *PONA* AND *AFIBETOYEN* YAM CULTIVARS IN TWO IMPROVED STORAGE STRUCTURES IN THE YENDI MUNICIPALITY

BY

ISSAHAKU ALIU (**PG9819213**)

JUNE, 2016

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A THESIS SUBMITTED TO THE SCHOOL OF RESEARCH AND GRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE OF M.PHIL IN FOOD AND POST HARVEST ENGINEERING

BY

ISSAHAKU ALIU (**PG9819213**)

JUNE, 2016

DECLARATION

I hereby declare that, this project is the result of my own research work and it has not been submitted for any other degree elsewhere. However, specific references of other people's work have been duly acknowledged.

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PROF. ATO BART-PLANGE Date

(Head of Department)

DEDICATION

I dedicate this work to Almighty Allah for granting me good health and guidance throughout the research period, and to my wife and my brother for their support.

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ABSTRACT

Two improved prototype storage barns (circular and rectangular) were constructed by the Improved Yam Storage for Food Security and Income Project (IYSFSIP) at Zang community in the Yendi Municipality to store white yam tubers (*Dioscorea rotundata*) for a period of four months. The objectives of the study were to determine sprouting rate, weight loss, rotting, shelf life and dormancy rate of two cultivars (*Pona* and *Afebetoyen*). It was found out that, the circular barn performed better than the rectangular one as it recorded average temperatures of 30.6 °C and 31.1 °C respectively with ambient temperature of 31.8 °C. Average relative humidity recorded in the circular barn was 52.1 % as against 53.7 % in the rectangular barn and ambient relative humidity was 53.4 %. *Pona* recorded averagely 31.5 % sprouting to *Afebetoyen* tubers which recorded 50.8 % in the circular barn, in the rectangular barn the reverse occurred; *Pona* recorded averagely 57 % against 51 % for *Afebetoyen*. Averagely 4.2 % of *Pona* got rotten as against 1.3 % for *Afebetoyen* in the circular barn. In the rectangular barn, the average amount of *Pona* that got rotten was 1.7 % and *Afebetoyen* was 2.10 %. Weight loss recorded 7.1 % averagely in *Pona* as against 7.8 % for *Afebetoyen* in the circular barn. However, in the rectangular barn both cultivars (*Pona* and *Afebetoyen*) recorded 8.9 %. *Pona* sprouts recorded 2.1 % and 0.94 % for *Afebetoyen* in the circular barn. In the rectangular barn, sprouts in *Pona* an average of 2.1 % against 1.2 % for sprouts of *Afebetoyen*. There was no recorded incidence of pest/rodent attack on any of the tubers in the two barns for the entire storage period. However it was observed that, the rectangular barn performed better than the circular barn in controlling tuber rot.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

CB:	Circular barn
C :	Degree Celsius
CRI:	Crop Research Institute
CSIR:	Council for Scientific and Industrial Research
IITA:	International Institute for Tropical Agriculture
KNUST:	Kwame Nkrumah University of Science and Technology
ME:	Moisture Evaporation
MiDA:	Millennium Development Authority
MLGRD:	Ministry of Local Government and Rural Development
MOFA:	Ministry of Food and Agriculture
MT:	Metric Tons
RB:	Rectangular Barn
RH:	Relative Humidity
SARI:	Savannah Agricultural Research Institute
T:	Temperature
YMADU:	Yendi Municipal Agricultural Development Unit
IYSFSP:	Improved Yam Storage for Food Security and Income Project
FAOSTAT:	Food and Agriculture Organisation Statistical unit
FAO:	Food and Agriculture Organisation
LSD:	Least Significant Difference

CHAPTER ONE

1.0 INTRODUCTION

Yam (*Dioscorea spp*.) is a vegetatively propagated tuber crop. It belongs to the plant family Dioscoreaceae and it is categorised among monocotyledonous herbaceous annuals or perennial climbing or trailing crops. The crop produces underground tubers and or aerial tubers which act as a source of food and feed for both humans and domestic animals. Yam is an important crop cultivated in Africa, Asia, Australia, the Caribbean, India, and in South Pacific (International Institute Tropical Agriculture report, 2010). Out of the over 600 species of the *genus Dioscorea*, six (6) are cultivated for food in the tropics (Hahn *et al*., 1987: Amani *et al*., 2004). The six (6) yam species suitable for eating are *Dioscorea alata* (water yam), *Dioscorea rotundata* (white guinea yam), *Dioscorea esculanta* (Chinese or lesser yam), *Dioscorea cayenensis* (yellow guinea yam), *Dioscorea bulbifera* (aerial or bulbils yam) and *Dioscorea dumetorum* (trifoliate or bitter yam) (Purseglove, 1972; Degras, 1993).

In Ghana, majority of the cultivated yams are cultivars of *D. rotundata* and *D. alata*. The white yam (*Dioscorea rotundata*) which originated in West Africa is considered to be the best quality species of yam cultivated for human consumption in the subregions (Gerardin *et al*., 1998). Even though, yam is cultivated almost everywhere in Ghana, a greater proportion is produced in Northern and Brong-Ahafo regions (Food and Agriculture Organization, 2013). The Northern region alone produced 1,337,701 metric tonnes of yam for the 2008 cropping season (MoFA, 2009). It is the highest cultivated field crop followed by groundnuts and maize. Other areas of production include Upper West, Volta, Eastern (Afram plains) and Ashanti regions. From these production areas, yam is exported all over the country and abroad (Tetteh and Sackwa, 1991).

Yam is among the main crops produced in Ghana and because of this, Ghana is considered to be the third largest producer of yam worldwide. The leading countries are Nigeria and Cote d'Ivoire. Ghana produced roughly four million metric tons of yams in 2005 compared to thirty-four million metric tons produced in Nigeria and five million metric tons produced in Cote d'Ivoire. The next country after Ghana is Benin, with a production of about 2.1 million metric tons and Colombia, Brazil, and Japan with smaller portions of production at round 200,000 metric tons in the same year (Millennium Development Authority, 2010). However, in terms of export, Ghana is leading with an annual export of about 12,000 tonnes (International Institute of Tropical Agriculture, 2008).

The crop adds more than 200 dietary calories per capita every day for more than a hundred and fifty million West Africans and many people earn a living through yam production (Babaleye, 2003; Andy, 2012).

1.1 JUSTIFICATION

Even though, yam production performs creditably well, the sector, in the time past, has faced numerous problems. Key among them include lack of credit facilities to increase production, lack of quality planting materials, pest and disease infestation during production and storage periods, erratic rainfall, poor soils and post-harvest losses at the farmer level (MiDA, 2010, IITA, 2008).

Farmers can only enjoy the fruits of their labour if only they can store the harvested tubers until the lean season (between May and August in the year) when prices are quite high so they can benefit. According to the Ministry of Food and Agriculture (MOFA, 2007) postharvest losses of yams in Ghana stood at 24.4 % and this must reduce further to a reasonable level. This can be achieved by proper storage management of yam after harvest.

The principal factors of post-harvest losses are weight loss as a result of evapotranspiration which is intensified by sprouting, rotting because of fungal and bacterial pathogen infestation, rodent attack and insect infestation (Bancroft, 2000) and sometimes injury to the tubers due to post harvest mishandling.

The traditional yam storage facilities being used currently by farmers for storage do not provide good environmental conditions in order to reduce post- harvest losses. They include adequate aeration, optimum temperature and relative humidity. Insects, rodent attack and direct sunlight on stored yam are all major challenges to the farmers. Regular inspection of produce is a basic requirement for successful and long term storage of yam tubers (Wilson, 1980; Lancaster and Coursey, 1984; Orhevba and Osunde, 2006).

Moisture on the tuber surface due to respiration can be prevented by enough ventilation and air flow. This also assists in removing the heat generated by tubers through same respiration process. Optimum temperatures are necessary to reduce losses when tubers sprout, respire and rot, while constant inspection is necessary to eliminate sprouts from tubers, rotten tubers, and also check the existence of rodents and pests.

Dormancy in stored tubers is the time after harvest during which germination is restrained. It is influenced by some factors such as the yam species, temperature and humidity of the storage surrounding. At lower temperatures, the rate of respiration is reduced, the formation of germ is delayed and the onset of sprouting can be prolonged leading to longer storage periods (Orraca-Tetteh, 1978; Knoth, 1993; Shiwachi *et al*., 2002).

However, traditional yam storage methods do not meet the above-mentioned factors leading to post-harvest losses of yam in Ghana,

1.2 OBJECTIVES

The main objective of the study was to determine the performance of two cultivars of white yam (*Pona* and *Afebetoyen*) in two different yam storage barns.

1.3 SPECIFIC OBJECTIVES

The specific objectives were to determine for the varieties of yams (*Pona* and *Afebetoyen)*

- the storage conditions in the barns;
- the sprouting rate in the two storage barns;
- the weight loss during storage; the shelf life during storage and the dormancy rates.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Root and tuber crops

African nations contribute approximately 23 % to the root and tuber crop production sector. The major root and tuber produced in Africa are: cassava (53 %) next is Asia (29 %) and South America (17 %); in terms of yam production, Africa’s contribution stands at 96 % in the world. However, Asia leads in sweet potatoes with 91 % and Africa contributes 7 %. With potato production, Africa is contributing 4 % in the world while Asia contributes 37 %. The rest of the world contributes 55 %. Other root crops coming from Africa is 70 %, followed by Asia which is 20 % (FAOSTAT, 2000).

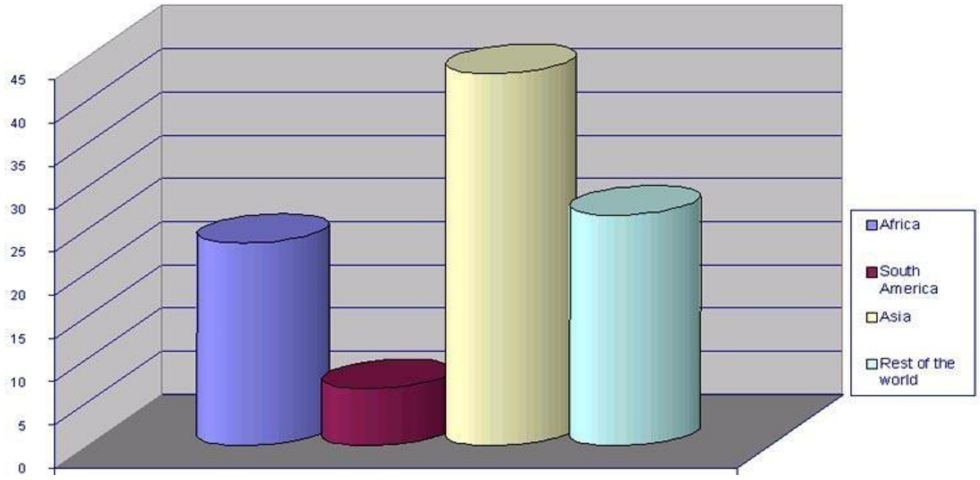

Figure 1: Production of root and tuber crops (in % of the total world production)

SOURCE: FAOSTAT, (2000)

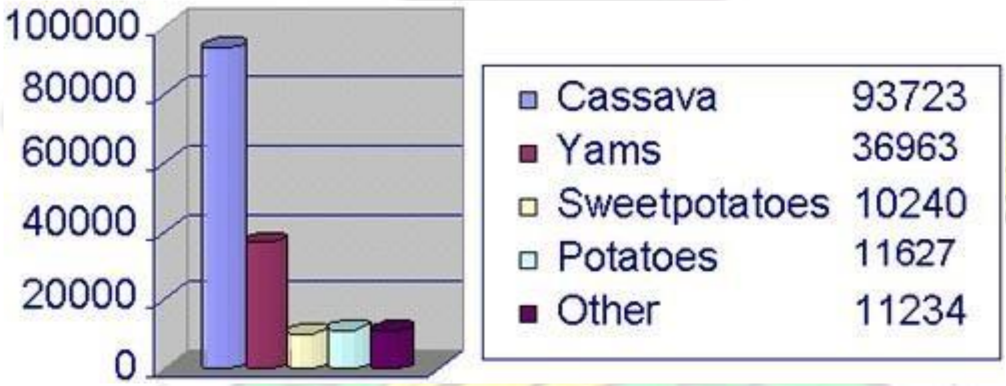

Figure 2: Production of roots and tubers in Africa (1000 Mt)

SOURCE: FAOSTAT (2000)

2.2 Yam Production In Ghana

2.2.1 Taxonomy

Yam is a monocotyledonous angiosperm, which belongs to the order Liliflorae, family Dioscoreaceae, and genus Dioscorea. It is viewed to be among the many most primitive of the angiosperms and includes over 600 species.

Out of the over 600 species of the genus *Dioscorea*, it is believed that six (6) are cultivated for food in the tropics (Hahn *et al*., 1987: Amani *et al*., 2004). The six (6) edible yam species are Chinese or lesser yam (*Dioscorea esculanta*), water yam (*Dioscorea alata*), white guinea yam (*Dioscorea rotundata*), yellow guinea yam (*Dioscorea cayenensis*), aerial or bulbils yam (*Dioscorea bulbifera*) and trifoliate or bitter yam (*Dioscorea dumetorum*) (Purseglove, 1972; Degras 1993).

2.2.2 Yam production distribution in Ghana

In Ghana, majority of the cultivated yams are cultivars of *D. Rotundata* and *D. alata*. Even though yam is cultivated all over the country, a larger proportion is produced in Northern and Brong-Ahafo regions (FAO, 2013).

Cultivation of yam alone in Ghana stands at 24 percent of total roots and tubers produced (MOFA, 2010). The spread of yam cultivation in the country is most times dependent on rainfall patterns. The crop needs rainfall of five months out of the eight months of vegetative period during growth and also fertile soils (Orkwo and Asadu, 1997; Sagoe, 2006). Generally, yams perform better in situations where 1,000 to 1,500 mm yearly rainfall is expected and evenly spread over six to seven months of the vegetative period.

As illustrated in figure 3, regions with the highest levels of production are concentrated in the central (Brong Ahafo and part of Ashanti region) and northern portions of Ghana.

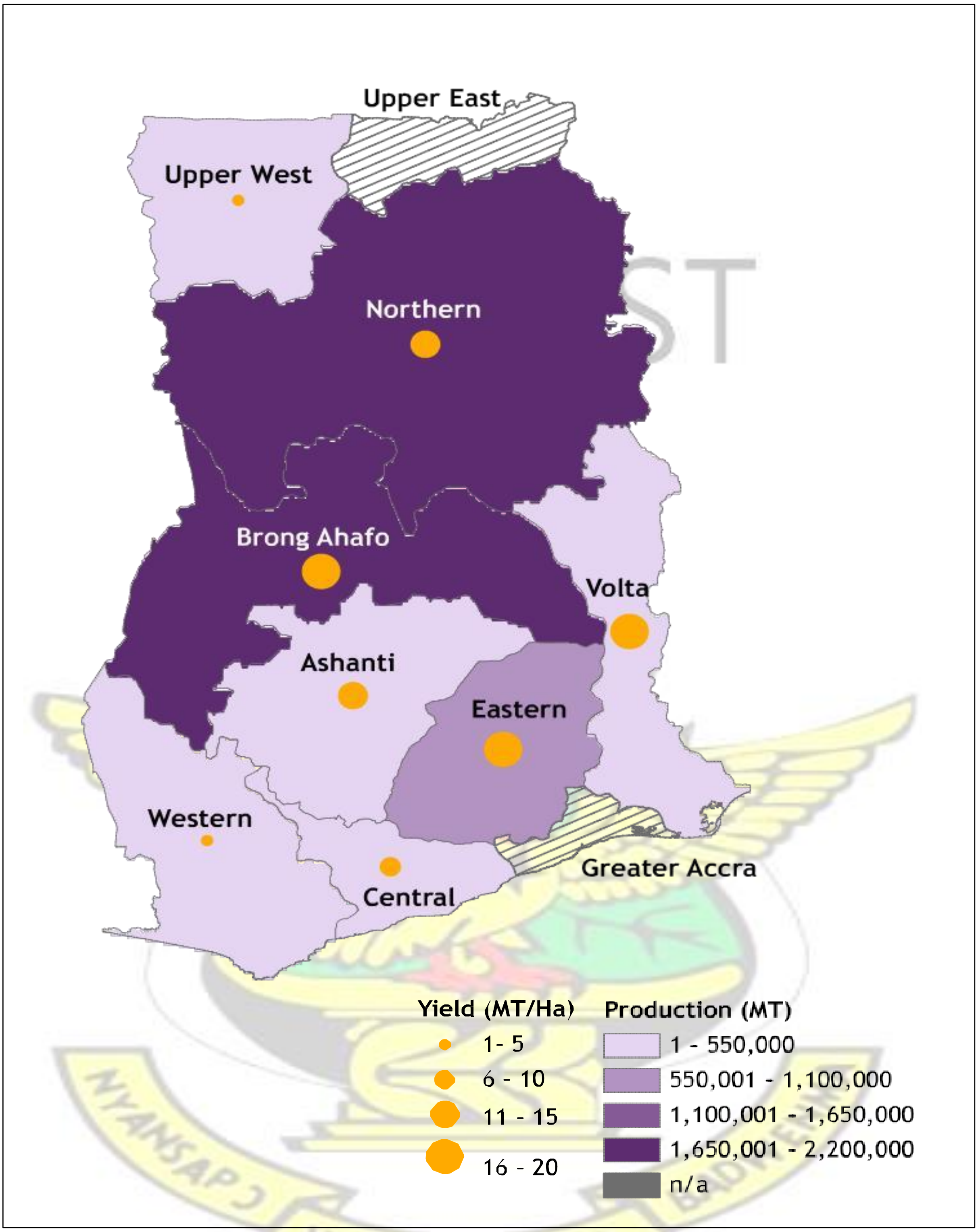

Figure 3: Yam Yields and Production by Region in Ghana, 2006

Source: (Environmental Protection Agency, 2012)

Figure 4 also indicates that yam production occurs in all regions, except for the Central, Greater Accra and Upper East. Brong Ahafo, Northern and Eastern Regions together produce about 76 percent of yam in the country. Brong Ahafo produces 39%, Northern region contributes 25% and Eastern region accounts for 12%. Upper West, Ashanti, Volta and Western Regions share the remaining 24% of production (Food and Agriculture Organization, 2013).

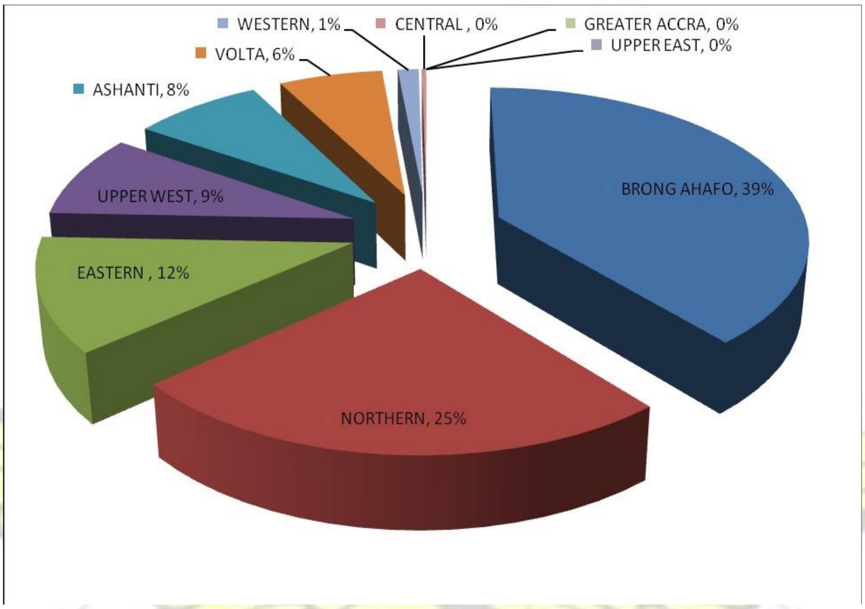

Figure 4: Percentage distribution of Yam Production in Ghana by Region, 2010

SOURCE: Ministry of Food and Agriculture, (2011)

2.2.3 Yam production and distribution in the northern region of Ghana

According to MoFA-Northern Region, yam production has covered the entire region. Figures from 2000 to 2008 indicated that, yam production increased significantly, despite challenges confronting the sector. Averagely, 366,186.42 MT were produced annually and maximum production stood at 1,078,354 MT in 2008. The minimum production was 47,3370MT in 2004 with East Gonja District leading with an average of 159,548.78 MT per annum. Bunkpurugu-Yunyoo trails with an average annual production of 45,138 MT.

Figure 5 below gives detailed yam production distribution in the region from 2000 production season to 2008 production season.

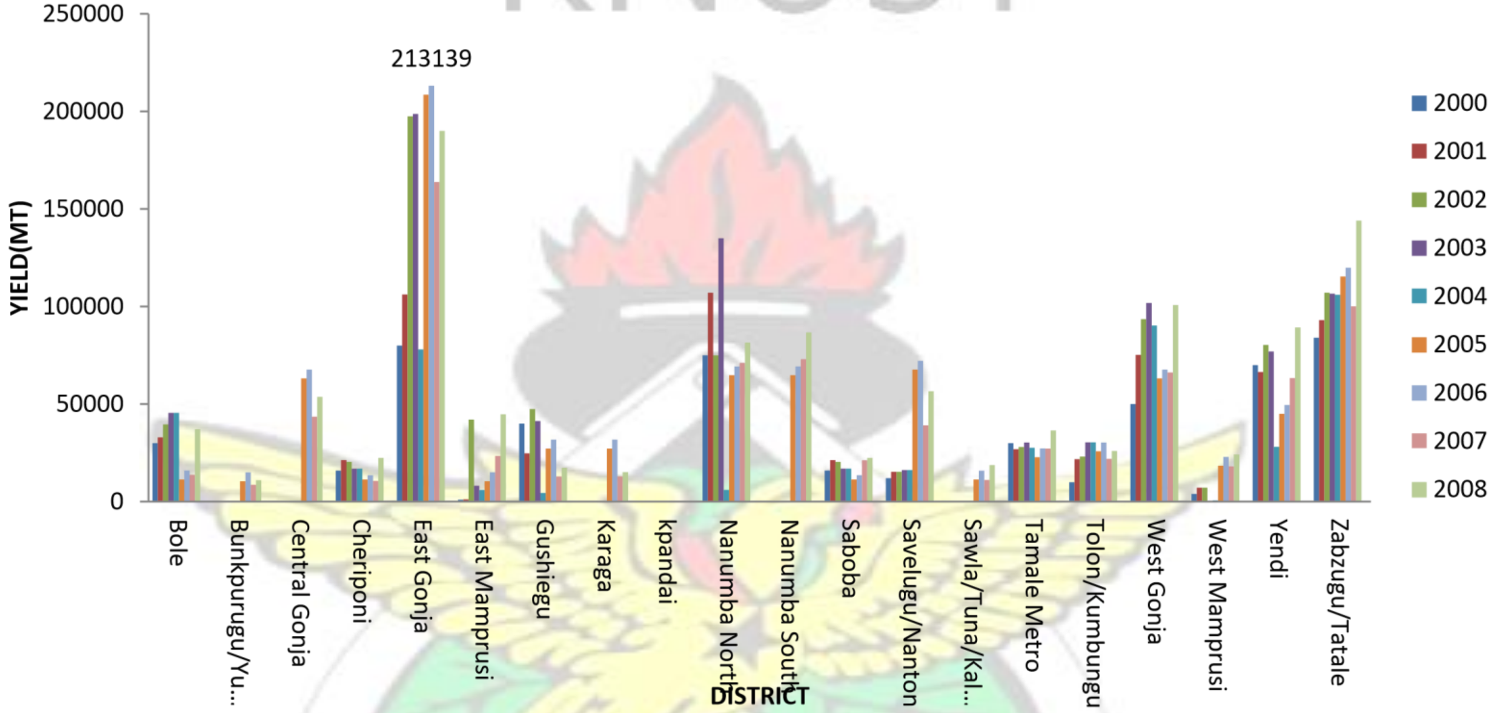

Figure5; Production trend in Northern region of Ghana (2000- 2008 cropping seasons)

2.3. Nutritional Value of Yam

The yam crop is considered to be the best supplier of some important nutrients such as vitamins (particularly, vitamin C), energy, carbohydrate, protein and minerals. Some varieties of yam tubers have been found to contain protein levels of 3.2-13.9% of dry weight. A yam meal could supply 100% of the energy and protein, 13% of the calcium and 80% of the iron requirement of an adult male (Knoth, 1993). Some yam foods have been shown to contain phosphorous and vitamins such as thiamine, riboflavin, niacin and ascorbic acid. Table 1 gives the ranges of nutritional content of yam consumed.

Table 1: Nutritional value of yam in 100 g

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

SOURCE: (Osagie, 1992; Osunde, 2008)

A tuber of yam is made up of moisture and dry matter. The dry matter is composed mainly of carbohydrate, vitamins as well as protein and minerals. Nutritional content of yam varies with species and cooking procedure. According to Osagie (1992), cooking with the skin attached helps retain vitamins.

2.4 Yam varieties grown in the country and their uses

Many of yam cultivars grown in Ghana belong to the *Dioscorea rotundata* and *Dioscorea alata* varieties. *Pona, Fushenbila, Afebetoyen or Olondor, Kpirinjo, Lilia, Limo, Bayire, Zong, Abihi-alla, Fuseini-billa, Kulkulga* etc. all belong to the white yam (*Dioscorea rotundata*) variety and are produced in the Northern region (Council for Scientific Industrial Research, 2012; Otoo *et al*., 2008). *Olondor* or *Afebetoyen* (D. *rotundata*) is another popular variety next to *Pona* (D. *rotundata*) in that, it can be stored for a longer period and therefore can be available throughout the year. *Manchisi* and *Akaba*, popularly known cultivars, belong to the water yam (*D. alata*) family.

Yams in Ghana are processed into various forms for consumption including *fufu*, boiled yam, roasted yam, or grilled yam; mashed yam; and chips (Peprah *et al*., 2010). The crop is one of the main supplier of the energy in the Ghanaian's daily diet. It is estimated to provide food to more than 150 million people in a day in West Africa (FAO, 2005). Yams are used mostly for their high carbohydrate content, they also provide protein, minerals such as calcium, phosphorus, iron and vitamins B and C (Splittstoeser and Rhodes, 1973).

The crop contributes enormously in food security and job creation in Ghana and can store better than some tuber crops in Africa. Yam sometimes, serves medicinal purpose to treat some sickness like diabetes, heart disorder (Undie and Akabue, 1986). Yam is respected everywhere and now has become part of our daily life especially in communities in which yam is produced. The traditional festivities like the *Homowo*, *Hogbetsotso*, and *Apoo* are new yam festivals in Ghana that accompany yam production and this suggests how the crop is viewed in society.

2.5 Yield losses

In Africa, an annual loss of about 500,000 tons of yam is projected to be caused by disease attack on the farm by agents like nematodes, fungi, bacteria, and viruses (Ikotun and Hahn, 1990). Another 1 million tons are lost during storage due to attack by insects, and nematodes, which facilitate invasion of organisms causing rot to the tubers (Emehut *et al*., 1998). In addition, severe losses occur during storage due to physical injuries and metabolic activity of tubers. The physical injuries appear during the growing period (yam beetles and, nematodes), during harvesting and digging
(especially for large-tuber varieties), or during transportation on bad roads (Coursey, 1967). Further losses then occur due to tuber respiration and transpiration. Finally, yam storage losses appear after the dormancy period had been broken creating room for tubers to start sprouting, which leads to a heavy loss of water and weight of the tuber (Nwankiti, 1988).

Pests include nematodes, insects, and vertebrates and the microorganisms responsible for yam diseases include fungi, bacteria, and viruses (Coursey, 1967).

2.6 Harvesting of yam

Harvesting of yam can be done in two ways, early and late harvests. The early or (milking) happen when the farmer is expecting to get yam sets for planting in the next season and tubers are first harvested in the midway to allow the plants to produce new tubers before the rains stop. Crops are harvested twice within the cropping season.

However, the late harvest occurs in situations where the tubers are allowed to mature fully before harvesting; this happens once in a cropping season (Onwueme, 1978).

2.7 Care during harvest, transport and storage

The skin of yam tubers can be injured. Extra caution is necessary during harvesting, transportation and storage. Damaged tuber surfaces pave way for microbial pest transmission and results in early spoiling due to rot (FAO, 1981). It is therefore important to maintain minimal damage for successful long storage (Plumbley, 1982). Careful handling of tubers during harvest, avoiding piling tubers at very high level during transporting, and also controlling tubers from falling are some precautionary measures (Sadik, 1987).

Postharvest loss is mainly caused by reduction in weight due to evaporation, sprouting, rotting normally caused by fungal and bacterial pathogens or insect infestations. These agents get into the tuber through wounds inflicted on tuber skins (Bancroft, 2000).

2.8 Yam storage

2.8.1 Conditions necessary for yam storage

According to FAO (2003), temperature reduction, aeration and regular checks on tubers are the most important three conditions necessary for successful yam storage. Aeration stops moisture from getting the tubers wet and also helps in cooling the barn after respiration has taken place. Optimum temperature is essential to check losses from tuber respiration, sprouting and rotting. However, optimum storage temperature should be around 12-15°C below which physiological deterioration such as chilling injury can set in. It is important to constantly check the tubers to eliminate sprouts, rotten tubers, and also check the activities of rodents and other pests (FAO, 2003). In all, tubers should be protected from high temperatures by providing good aeration during storage.

The storage surroundings must also restrict the onset of sprouting which increases the rate of loss of dry matter leading finally to shrinkage and rotting of tubers. Both consumable yam and seed yam have the same storage requirements.

Yam cultivation, unlike that of cassava, is seasonal and should be preserved several months by proper storage. The break of tuber dormancy (when tubers start sprouting) is the big challenge to long term storage. Constant removal of the shoots prolongs shelf life.

Approximately 16 °C temperature and 70 % humidity are said to be good storage conditions for cured tubers. At a temperature beyond 16 °C, yam can store for 3 to 4 months. Tubers which are treated should be stored at a relatively low humidity. However, below 12 °C chilling injury can occur.

2.8.2 Curing yam before storage

After harvesting, tubers of yam should be thoroughly treated as early as possible to enhance the development of a hard cork lining. Treatment can take place closer to the area the yam will be kept in order to reduce handling after curing. This activity should happen within seven days of harvesting at temperatures between 32-40 °C and a relative humidity of 85-95 % (FAO, 1989). This can be done in two ways.

2.8.3 Above ground curing

Tubers are packed on the ground and covered with dry grass at least 15 cm thick and finally covered with jute sacks and not polythene (Figure 6). The treated tubers should not be exposed to sunlight and the cover should be removed after 4 days (Knoth, 1993).

2.8.4 Pit-curing

Pit-curing is a widely used system in parts of Nigeria. It consists of a pit dimension of approximately 2.5 x 1.5 x 1 m with the under lined with dry grass or sawdust. The yam tubers are placed on this lining and then covered with a thin layer of soil. This can take about two weeks after which the tubers can be transferred to a permanent barn. Trials conducted in Nigeria, showed that, yam tubers treated for two weeks by this method showed only 40 % rotted tubers after 4 months of storage, compared to 100 % of untreated tubers (Knoth, 1993).

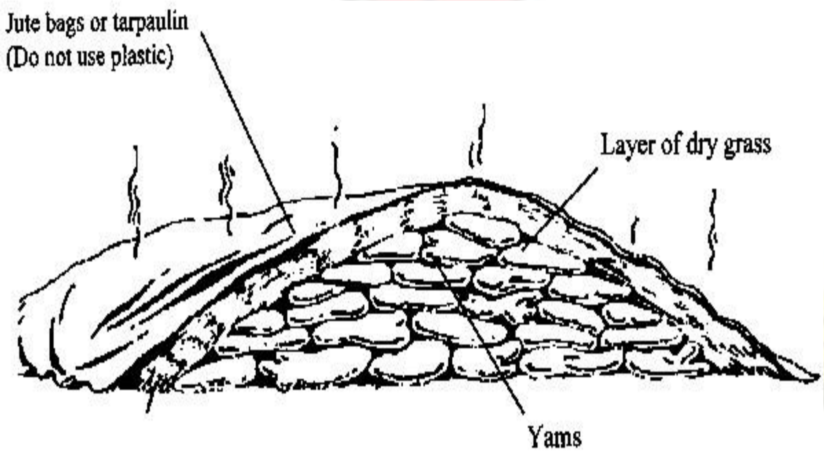

Figure 4: Above-ground curing of yams (FAO, 1987)

The two curing methods are dependent on high temperatures and high relative humidity, because these conditions also favour the formation of fungi and bacteria. Demeaux and Vivier (1984) advised that prior to curing the tubers should be treated with lime wash or wood ash, or if available, an appropriate fungicide such as Thiabendazol or Benomyl. After curing the tubers should be handled with care to avoid new injuries.

2.9 Factors to consider during storage

2.9.1 Storage climate

In the course of yam storage, respiratory activities take place in order that, the tuber can be viable and can also reproduce. However, the volume of respiration or transpiration is dependent on the structure. Additionally, the storage climate, i.e. temperature and relative humidity, influence this.

2.9.2 Temperature in the barn during storage

In most cases, temperatures at low level can determine how long tubers can store in the barn. This is because, respiration is low when temperatures are lower and that also delays germs formation within the tuber. Depending on the yam variety, storage temperature should be between 13-15 °C (Demeaux and Vivier, 1984).

As a result, when temperature is reduced to increase stored yam quality could be very restricted and this should not be under 15 °C. Even if one does not use energy devices for cooling and how to maintain the figure can be difficult in the tropical environment. Using extra power sources also makes the building to be closed and insulated yam barns and this cannot be possible in small-scale farm due to the cost involved.

Reduction in temperature extends yam storage period. As a result, all available possibilities for this which can be economically possible should be made use of little changes in the building of indigenous storage barns in order to benefit the temperature rise and fall between day and night. Growing shady tree around storage barns and moisture evaporation by air currents may additionally result in an appreciable reduction in storage temperatures and for that reason this can help to improve storage climate (Demeaux and Vivier, 1984).

2.9.3 Relative humidity of the air

When produce is stored in a barn, there may be an interchange of moisture between the stored tubers and the surrounding in order to achieve an equilibrium moisture content of the tubers and its immediate environment. Grains, for example, have a tendency to take in moisture from the immediate environment. Yams with much water in them, are likely to give out water to their surrounding when they are stored.

Moisture loss from tubers in store is undesirable because it is beneficial loss and not also improves the quality. As a result, environment in the barn should possess humidity rates which reduce the transfer of moisture between tubers and the surrounding in the barn. 26-28 °C temperatures is recommended for West Africa during yam storage and relative humidity of 70-80 % leads to an equilibrium, where the transfer of water between the tuber and its environment may be very low (Demeaux and Vivier, 1984).

Under these storage conditions, the tubers maintain their qualities such as colour, aroma, flavour and chemical composition. Excessive moisture can bring about moisture falling on tubers which speed the process of mould formation on the tubers.

In adapting, means that can regulate moisture presence, only those which are technically and financially possible for yam producers must be considered. In the foreground there are changes in barns construction which promote air exchange and hence removal of excess water from the store. Changes in construction may also be supported by selecting a suitable location where air exchange is encouraged.

2.9.4 Promoting ventilation

Oxygen supply from moisture evaporation air is important for the metabolic functions to retain the life of the tubers during storage. Tubers in the barn also release water vapour and carbon dioxide at the same time. If the composition of the atmosphere in the storage barn deviates from the average condition of the air as a result of the metabolic process can have an effect which is unfavourable on the stored yam condition.

Too much moisture in the air can condense on tubers if the temperature falls and this promotes tuber rot during storage. Minimal concentrations of oxygen restrict respiration and promote unwanted fermentation of tubers in storage. Higher carbon dioxide and ethylene concentrations in a yam barn are also not desirable. Tuber cell structure destruction can be realized due to high carbon dioxide concentration. Ethylene promotes germination since it is a growth hormone (Batista, 1990).

For the reasons above, changes in the composition of the tuber surroundings during storage are not preferred as these can have a negative effect on stored tubers. To prevent undesired changes in the atmosphere, yam barn need to be sufficiently ventilated. Ventilation does not only promote gas exchanges between tubers and the atmosphere but also affects the temperature in a storage barn.

How to control ventilation is not simple and easy and can lead to counter-productive effects. If, for instance, the barn is poorly aerated in the day, it can increase temperature inside the barn that can bring about unwanted warming of the stored tubers of yam. Poor aeration and low relative humidity lead to tuber drying during storage. The barn needs to be well aerated at night, as practically as possible, since temperatures are lower during the night and relative humidity in the day, in most cases, is higher (Sadik, 1987).

In considering different improvement measures to enhance ventilation it must be as simple as possible to carry out and not incur any extra cost. In situations where storage barns are to be newly constructed, locations that allow natural air flow by means of air currents should be chosen. Aside this, the tubers must be stored in order that air flow will not be hindered. Piling tubers in a huge heap and in trench silos are also not suitable and compatible to satisfy the demands of sufficient ventilation.

2.9.5 Providing shade for storage facilities

On one hand, the direct influence of daylight on stored produce increases storage temperatures. However, moisture evaporation and formation of germs is promoted by this. Therefore, the store will have to be sufficiently shaded.

Enough shade can be achieved during constructions where storage barns are protected by using a roof. Roofs must be made from plant materials that can be acquired locally for not only to beat the cost involved down but also due to the high heat insulation they provide.

The roofs do not only keep the sun rays off the tubers but also protects stored tubers from rain which promotes tuber rot. Apart from the barn roofs, evergreen trees should also be planted around the barns to provide natural shade as it also protects the stored produce against high temperature. In constructing the roofs for shade and planting trees around, care must be taken in order not to compromise the ventilation.

2.9.6 Tuber rot control

As indicated earlier, tuber rot is caused most times by fungus and bacteria pathogens. These pathogens can only penetrate into the tuber through damaged spots, like injuries or holes made by nematodes.

Careful handling of tubers will consequently minimise risk of damage to the tubers during harvest, transportation and storage. Rotting tubers at the time of storing can be put to other use.

The effect of rot can also be reduced by curing processes and this can be done by closing all tuber wounds to prevent agents causing rotting from entering the tubers. Traditional methods such as ash and lime dust can be used to treat the tuber wounds (Onwueme, 1978).

Because rot can be transferred from tuber to tuber, stored tubers must be constantly checked, on a regular basis, in order that infested tubers can be eliminated from the barn in good time without affecting the rest. Fungicide treatments to the tubers are also rot control measures and Thiabendazol and Benomyl are recommended for yam storage (Demeaux and Vivier, 1984).

2.9.7 Nematode control during storage

Nematode control can happen at the same time putting measures against agents of rot which often follow the nematodes activities and normally cause severe injury on tubers than nematodes themselves.

Root and tuber parasites such as nematodes are spread by infested plants. Based on this, best plants that are free from nematodes must be used for vegetative propagation.

Additionally, as nematodes live freely in the soil, crop rotation (long period between the planting of two yam crops) can be practised to bring down the pest pressure. To achieve this, it must be noted that, most nematodes which are parasites on yams additionally have other host plants.

2.9.8 Control of insects damaging stored produce

According to Wilson (1980), measures to deal with insect damage in yam barns have two functions: firstly, the injury caused by insects (eating and loss of quality) are, at least, reduced or avoided. Secondly, control measures are to prevent secondary damage caused by rot pathogens which will penetrate the tuber wounds on tuber skin brought about by insect damage.

Separation of damaged and healthy tubers can also work. In some circumstances, for example, with the yam moth, this is problematic since infestation cannot at all times be determined externally. For hygienic reasons, all parts of the tuber that are infested by pests must be destroyed and not kept closer to the barn (Wilson, 1980).

2.9.9 Measures for protection from mammals

To take good care of tubers against mammals, measures will depend on the species and the kind of storage method. For example, fencing can keep domestic animals away from the yam barn. Yam barns constructed on platforms provide good protection from animals which could damage stored tubers. This kind of barn can be protected easily from rats by mounting rodent guards (metal funnel) on the stands (Wilson, 1980). Rodent guards are mounted on the stands with the wide end facing downward at a height of 100cm to prevent rats and other rodents from passing the obstacle.

2.10 Various yam storage methods

In Africa, there are different methods of storing yams after harvest and these vary from one area to the other. These methods range from delayed harvests to modern improved storage methods. The use of any of these methods will depend on location, production level and also the cost involved.

2.10.1 Traditional yam storage

In this method, yam harvesting is delayed, most importantly, when it is not raining. In this case, tubers can remain in the soil without appreciable loss of quality.

Basic yam barns are designed with upright frames of 2 m or more high to which individual yam tubers are tied with a rope along cross tubers of weightless wood or timber. The yams may also be tied to the vertical poles so that the axis of the tuber lies in the horizontal plane. Palm leaves can be used as thatch roof or the barn can be constructed under a shade of group trees. It is important for the barns to give enough aeration and guide against termites and theft. Tubers should be checked daily if possible and rotting tubers should be removed immediately to prevent infecting the healthy ones. Right after the start of the rainy season tubers in the yam barn begin to rot faster.

Cured tubers in the huts, normally kept in the form of heaps on the floor, in boxes or on shelves or even racks in such a way that air can pass everywhere. The higher the temperature and the relative humidity, the more aeration is required (Wilson, 1980.)

Earthen silos can also store small amounts of well dried tubers of yam. Yam also can keep in pits or piled into heaps and guided against sun and ground water.

2.10.2 Losses in traditional yam storage

Tubers of white yams can be stored for several months if kept under better storage conditions and constant checks since yam is a seasonal crop. However, the traditional barns usually encounter appreciable losses due to bacterial and fungal rotting, rodent attack, sprouting and other factors including theft. Consequently, over one million tons of tubers may be lost per annum during storage in West Africa (MiDA, 2010). Yam tubers are very delicate and can be bruised easily during harvesting and handling. They spoil quickly due to physiological decay and rot. High temperatures may result in considerable physiological losses even to healthy tubers. Rodents and other pests including insects attack the tubers, which are even more susceptible to rotting, once they have been wounded by pest organisms. The sprouts also occur easily and reduce the quality of the tubers and therefore, the sprouts should be constantly removed. The amount of loss depends in the first place, on the method used in storing the tubers, the variety and duration of storage.

The indigenous or traditional yam storage methods such as pits, trench silos and heaps in the field are very difficult to handle because, they cannot protect the yam tubers sufficiently from losses described earlier. Constant checking of tubers is very difficult and, in some cases, impossible in most of the traditional storage barns so that losses are only detected when the yams are removed from the store for use or for sale. In many cases, the farmer cannot quickly sell when market prices are good because of the poor access to the store, poor road conditions, especially in the rainy seasons.

External view of tradition barn Internal view of traditional barn

Figure 5: Traditional storage barns in the Yendi Municipality

In the traditional storage method tubers are heaped in circular or rectangular structure constructed with zanna, wood poles, rafters and the top is covered with sorghum straw to protect the yam from direct sunlight. It could be constructed under trees.

Figure 6: Heaped tubers of yam under a tree covered with vines

A second method involves heaping harvested tubers under a tree and covering it with the stakes coiled with yam vines and sometimes topped up with dry grasses as shown in figure 8. Key disadvantages among the two methods include exposure to rain, rodents and insect attack and sometimes tubers are not protected properly from direct sunlight.

2.11 The improved traditional yam barn

In order to reduce losses and ensure long term storage, the yam barn gives the best outcome compared to other different storage systems across West Africa (Wilson, 1980). This is why the yam barn is selected as the basis for improvement measures to traditional systems of storage.

The traditional yam barn has some disadvantages. As a result, the following features must be enhanced:

The roof should be constructed similar to that of a hut and should be made of local material such as straw or palm leaves and should cover the barn properly.

Roofs made of plant materials do not only provide tubers with sufficient protection from sunlight and rains but also regulate temperature fluctuation due to its insulation characteristics. However, the height of the roof should be at least 2.5 metres to allow constant ventilation (FAO, 1990).

Rodents and domestic animals should be prevented from getting closer to the barn. This can be done either by fencing made of oil drums which have been cut open or a wall constructed at least one-metre high as rodents can easily overcome a wall (not like an oil barrel barrier). The space between the top of the wall and the roof should be covered with fine wire mesh. It is important that the barn is provided with a door which closes well in order to avoid theft.

Within the modified yam barn the tubers are stored on multi-stage shelves. The shelves may also be constructed with various locally available materials so far as they provide enough support. The lowest shelves should be about 50 cm above the floor so that no moisture is absorbed from the ground.

The shelves should be arranged in order to allow visual inspection of the tubers quickly and all around. To facilitate this, the tubers should be stored in two or three layers on every shelf. It will also restrict an excessive amount of weight pressure on individual tubers and consequently reduce the hazard of bruising.

The choice of the site is very essential in utilising the advantages for the system. This will have to be chosen so that natural air movements can be used for ventilation purposes. The barn must be constructed sideways to the wind direction in order that the natural air can be used to its full effects. Existing natural sources of shade, such as trees, should be taken into consideration during site determination as temperature within the barn can also be reduced by these.

The natural shade and its temperature reduction effect can provide strong ventilation during the day. For this reason it must be understood that not too much scorching air enters the barn as ventilation during the day time.

2.12 Factors influencing yam storage

Before one can succeed in yam storage, one need to use healthy and sound tubers, and apply proper curing if possible together with fungicide group; enough aeration to remove heat generated by respiration of sprouts and rotted tubers that develop, monitoring the presence of rodents and protection from direct sunlight and rain.

Yams can be stored best in a cool, dry and well ventilated surrounding where yam seeds and commercial yams have similar storage requirements, notwithstanding cultivar differences. Fresh yam tubers can be successfully stored in ambient and refrigerated conditions and the recommended storage temperature is between the ranges of 12-16 °C. Optimum conditions of 15 °C or 16 °C at 70-80 % relative humidity have been recommended for cured tubers. (Cooke *et al.*, 1988; Opara, 1999).

Storage environment for yams must inhibit the onset of sprouting (breakage of dormancy) which increase the rate of dry matter and subsequent shrivel and rotting of tubers. Tubers transit and storage life of 6-7 months can be achieved under these conditions (Plucknett, 1979; Passam *et al.*, 1978; Opara, 1999).

Yams must be in an atmosphere where conditions that favour the growth of microorganisms are prevented or discouraged. The essence of maintaining such conditions is to avoid the causative agents of spoilage or storage losses in the produce. The major factors influencing the growth and productivity (reproduction) of microorganisms in yams include moisture, temperature, relative humidity and the soil type (Kay, 1973).

To store yams effectively, moisture should be controlled at sufficiently low levels so that other factors do not set in. Also, the type of soil conducive for storage is taken into consideration.

There are considerable variations in the storage of different varieties of yam. *D alata* is more difficult to store than *D. rotundata*. Under high storage temperatures (16 ^{o}C and above) and relative humidity (85 % and above) sprouting and decay occurs in water yams (*D. alata*) as compared to *D. rotundata* (Maduewese and Onyike, 1981).

However, at high temperatures and lower humidity the case is the same. This is because water yam is water stressed and cannot stay long. Thus, for water yams to be stored, they will require lower temperatures and lower humidity. For instance, by burying the tubers inside the ground and covering properly with earth, it can last a few weeks until it is ready for use (Maduewese and Onyike, 1981).

2.13 Dormancy in Yams

Dormancy is the temporary suspension of visible growth of any plant structure containing a meristem. In yams, it is that period during which sprouting is inhibited.

Knowledge of the potential length of dormancy for stored tuber is important because once dormancy breaks, the tubers also senesce rapidly with loss of stored food (carbohydrates) (Coursey, 1967; Coursey, 1983).

The environmental conditions affecting yam tuber dormancy are photoperiodicity, white and coloured light, temperature, relative humidity and partial oxygen pressure. The length of tuber dormancy is endogenously controlled and conditions such as availability of soil moisture or cool temperature are ineffective triggers of sprouting.

The physiological age of tubers also affects their readiness to sprout. Approximately 6 months after harvest, dormancy disappears completely and budless set planted after that period must require nearly the same time to sprout (Onwueme, 1978).

2.14 Production steps of yam in the Northern Region

According to farmers in the Zang community, where the study was conducted, yams are usually planted between January to February every year and harvesting normally starts in November to December depending on the variety. Some varieties are early maturing while others are late maturing.

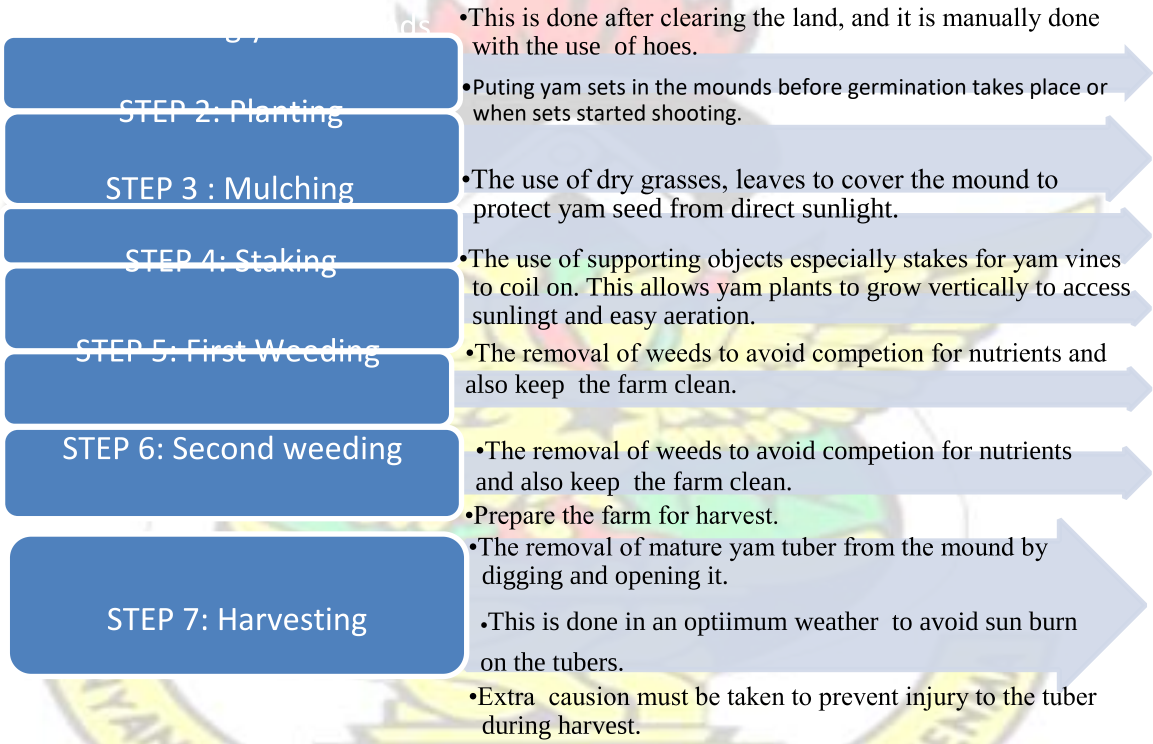

Figure 7: A flow diagram of yam production steps in the area (Agronomic Practices)

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Geographical description of the Yendi Municipality

The study was carried out in the Yendi Municipality in the Northern Region of Ghana. The area population is estimated to be 54,411 people constituting two main tribes; Dagombas and Konkombas who mostly farmers. The Municipality is characterized by savannah vegetation and average annual rainfall between 1000-1500 mm. Yendi is located within eight other districts, to the east with Saboba, Zabzugu and Tatale/Sangule Districts; to the south, with Nanumba and East Gonja districts, to the West, with Tamale metropolitan and Savelugu/Nanton Municipal and to the north with Gushiegu district (Yendi Municipal Assembly, 2006). Specifically, Zang

Community was chosen for the project. This was done in collaboration with MoFA, Yendi. Zang is 2.5 km from Yendi and the first community moving from Yendi to Zabzugu.

3.2 Survey

A simple random sampling method was used to administer questionnaires to fifty (50) yam farmers in the area to have first-hand information on postharvest management of yam and also to enable the selection of the right varieties for the study. Results of the survey indicated that, 66% of respondents selected *Pona* as the best cultivar, followed by *Afebetoyen* with 26 %.

The selection was based on high economic value, household food security, long shelf life and high consumer preference. The survey also gathered information on challenges farmers face during the postharvest management of yam during storage.

Two cultivars of white yam (*D. rotundata)* were finally selected (*Pona and Afebetoyen*) by respondent farmers for the reasons below;

- they were highly demanded by consumers;
- they served as household food security in the food crop area; and
- they were believed to have a longer shelf-life (especially, *Afebetoyen*) than other cultivars.

3.3 Storage Barns

The two yam storage barns for the study were constructed before the study started. Two different prototype barns were constructed with local materials such as zanna mat, thatch grasses and teak that could be found easily locally and were also costeffective. Carpenters within the community constructed the barns supervised by Engineers from the Agricultural Engineering Department of the Kwame Nkrumah University of Science and Technology (KNUST) and Council for Scientific and Industrial Research of Crop Research Institute (CSIR-CRI), Kumasi. Circular and rectangular barns, capable of storing between 4000-5000 tubers each were constructed. A sample view of the barns is presented in figure 10.

Figure 10: External view of the barns

3.4 Stocking Procedure

A total of nine hundred and sixty (960) tubers of healthy, freshly harvested tubers of *Pona* and *Afebetoyen* were selected. Each cultivar constituted four hundred and eighty (480) tubers and each storage barn received two hundred and forty (240) tubers of each variety. The tubers were randomly selected and put into four (4) groups totalling sixty (60) tubers per group. For easy handling, each group was further divided into four (4) sub-groups which constituted fifteen (15) tubers for each of the two cultivars. This meant that, each of the two barns contained thirty two (32) groups of 15 sets, of both *Pona* and *Afebetoyen*.

Table 2: Outlay of how yam stocking was done

GROUP	A				B				C				D			
SAMPLES	A_1	A_2	A_3	A_4	B_1	B_2	B_3	B_4	C_1	C_2	C_3	C_4	D_1	D_2	D_3	D_4
NUMBER OF TUBERS	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
TOTALS TUBERS	60				60				60				60			

3.5 Weighing the samples

Each sample (A_1, A_2, A_3 ….. D_4) was weighed using the hanging weighing scale to determine the initial weight of each sample. A sample of (15 tubers) was put into a jute sack and hung on a weighing scale and the weight recorded. This was applied to all the 32 samples in both barns. Figure 11 shows how the weighing was carried out.

Figure 11: Weighing of samples

3.6 Stocking the barns

After weighing, the tubers were checked for sprouting, rodent attack, tuber rot and physical wounds and these were recorded. Each sample was kept on the shelf with a tag containing sample identification. Data was collected for a period of four months starting from 14th February to 13th June, 2015.

Figure 12: Tubers on shelves in the barn

3.7 Monitoring and data collection

Parameters were monitored monthly over a period of four months from 14th February to 13th June, 2015. Temperature and relative humidity within and outside the barns were also monitored over the same period using Tinytag Data Logger. However, in order to be consistent and to avoid possible changes, it was decided to use group B samples for the monitoring for them in order to have uniform data.

3.8 Analysis of results

The results were analysed using Microsoft Excel and GenStat (Twelfth Edition) software.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

4.1 Results

The results on the different yam storage barns are presented and the salient features discussed in this chapter.

4.1.1 Pre-storage conditions inside and outside (ambient) the barns

Before the two barns were stocked, the temperature and relative humidity within and outside the barns were monitored. Data loggers were installed inside and outside the two barns to read temperature and relative humidity. These loggers were calibrated to take hourly readings (24 times daily). Daily diurnal temperatures and relative humidity within and outside of the two barns were recorded for a period of one month from **14th** December, 2014 to 17th J January, 2015 before storing the yams (Figures 13, 14, 15 and 16).

Minimum temperature within and outside both barns read the same values and ranging between 15.8-24.9 °C as against the outside temperature which ranged from 15.7-24.6 °C. Temperature was high in December 2014 and declined towards January 2015.

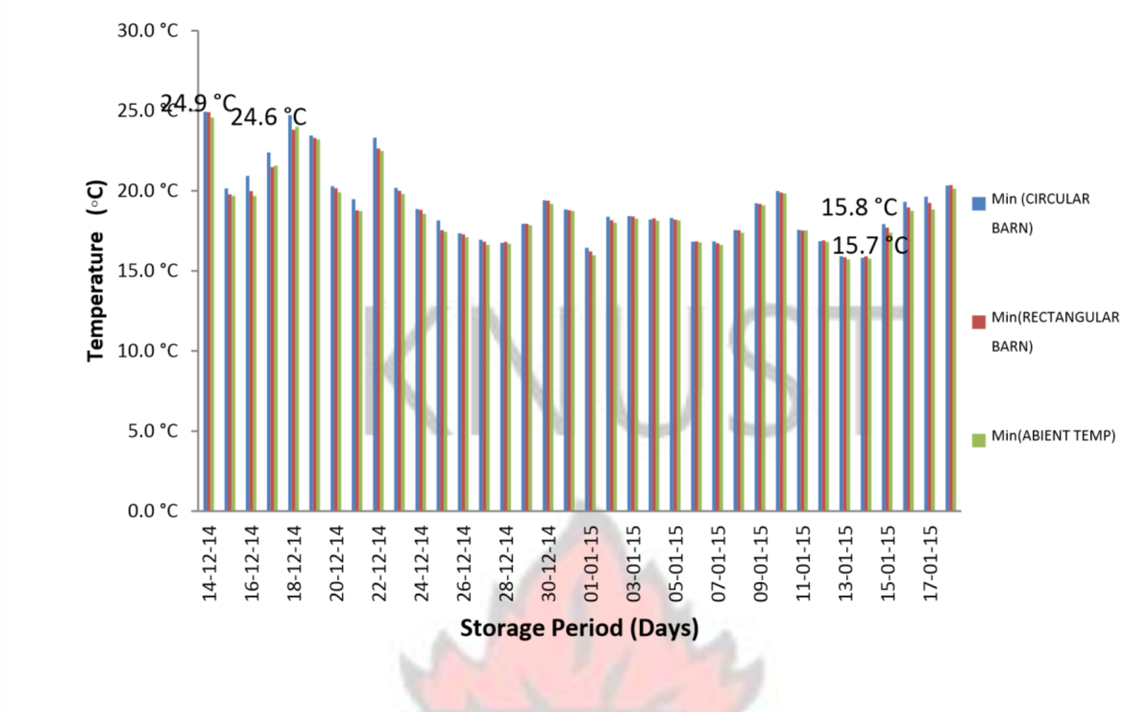

Figure 13: Daily minimum temperatures before storage

Figure 14 also shows maximum temperatures within and outside the two barns. The circular barn had maximum temperatures between 30.4-36.3 °C against the rectangular barn in which temperatures ranged from 28.7-37.0 °C and the outside temperatures read between 29.3-37.9 °C.

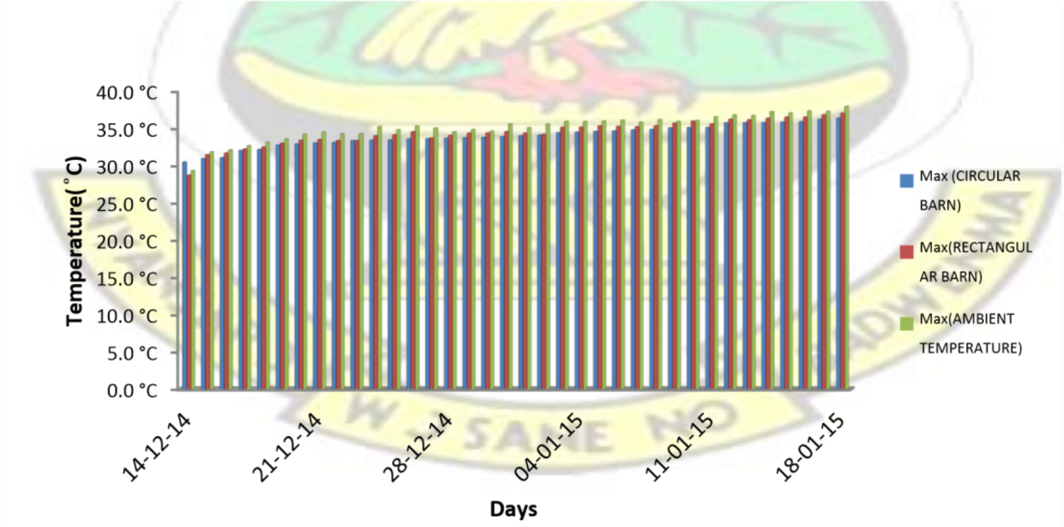

Figure 14: Daily maximum temperatures before storage

On the other hand, minimum relative humidities within the two barns indicated that, the circular barn had minimum relative humidity ranging between 8.4-27.0% while the rectangular barn read between 8.2-27.1% and the outside relative humidity ranged between 8.9-27.6% (Figure 15).

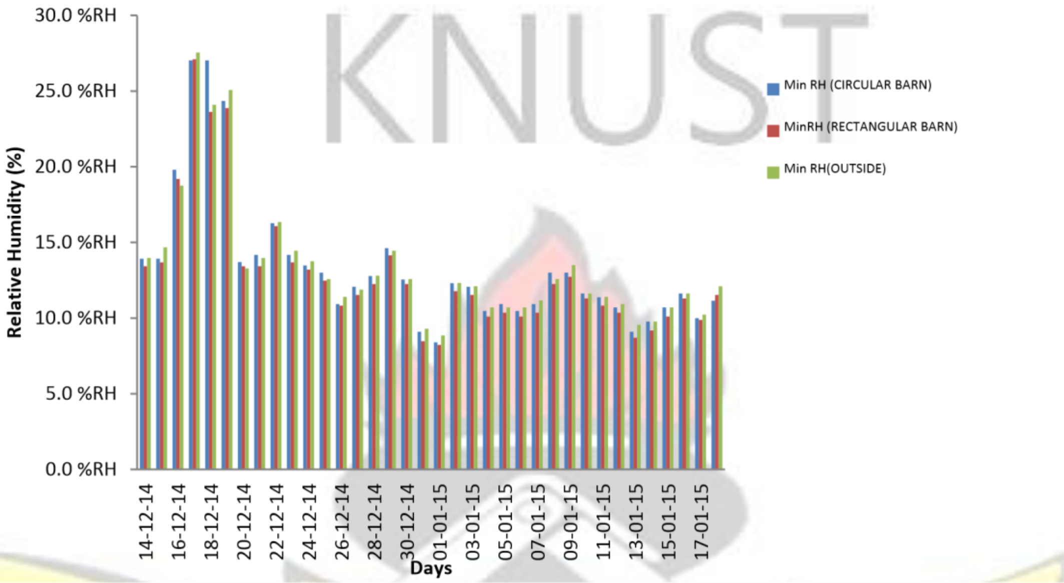

Figure 15: Daily minimum relative humidity within and outside barn (before storage)

Maximum relative humidity also showed readings of 18.9%-64.3 % within the circular barn against 19.2%-67.6 % for the rectangular barn and the outside stood between 20.0%-67.1 % (figure 16).

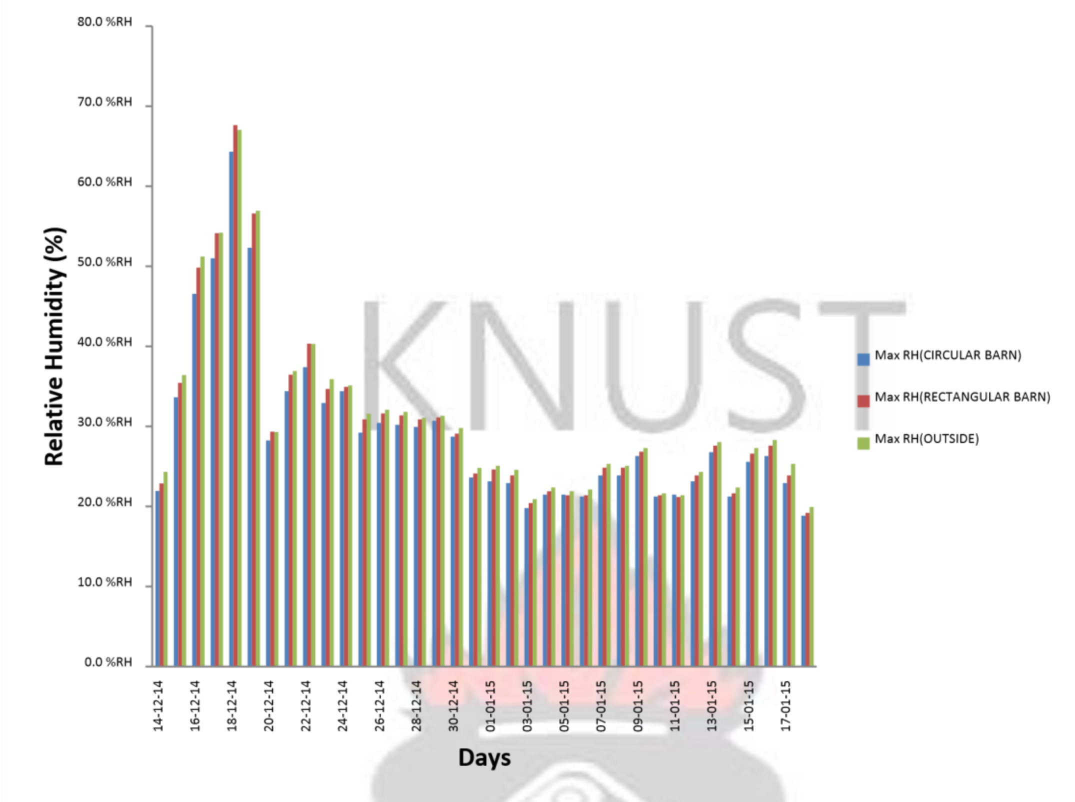

Figure 16: Daily maximum relative humidity within and outside the barns (before storage)

4.1.2 Daily temperatures within and outside the barns during storage

Temperature and relative humidity readings were taken during the four-month storage period to observe the temperature and relative humidity conditions between the two barns. This was done using the same data loggers which were programmed to take hourly readings from 14th February to 13th June, 2015.

Figure 17: Data logger reading temperature and relative humidity

An arrow in figure 17 shows a data logger.

4.1.3 Minimum temperatures within and outside the barns during storage

Daily temperatures within and outside the barns were recorded and were segregated into maximum and minimum readings. Figure 18 shows daily minimum temperature of the inside and ambient temperature of both barns. The circular barn had varying temperature values ranging between 21.5-31.4 °C, while the rectangular barn temperatures ranged between 21.2-30.4 °C and the ambient values ranged between 21.3-30.1 °C.

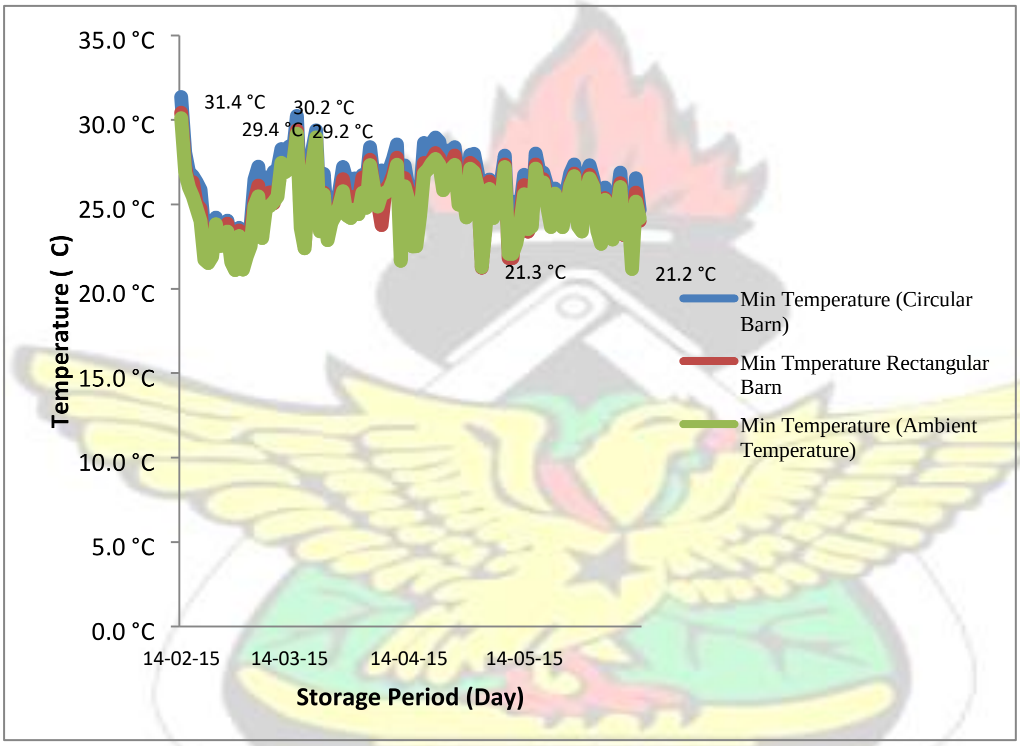

Figure 18: Minimum temperature readings within and outside the barns

4.1.4 Maximum temperatures inside and outside the barns during storage.

The daily maximum temperatures recorded ranged between 28.0-39.4 °C in the circular barn but ranged between 27.2-43.5 °C in the rectangular barn. The ambient temperatures ranged between 27.6-45.6 °C (figure 19).

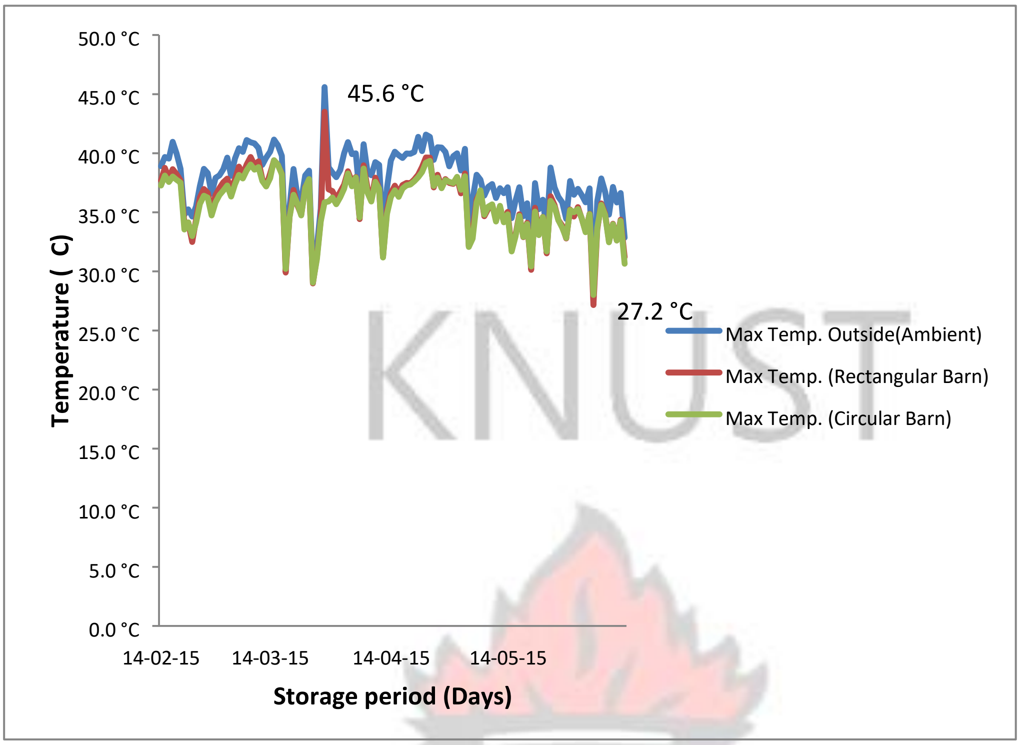

Figure 19: Daily maximum temperature readings inside the barns and outside during storage

4.1.5 Relative humidity monitored

4.1.5.1 Minimum relative humidity in the day

The minimum daily relative humidity (RH) during the experiment within and outside the two barns ranged between 0.0%-71.7 % RH in the circular barn, 6.8-72.2 % in the rectangular barn and 0.0%-71.1% outside the barns (ambient) (figure 20).

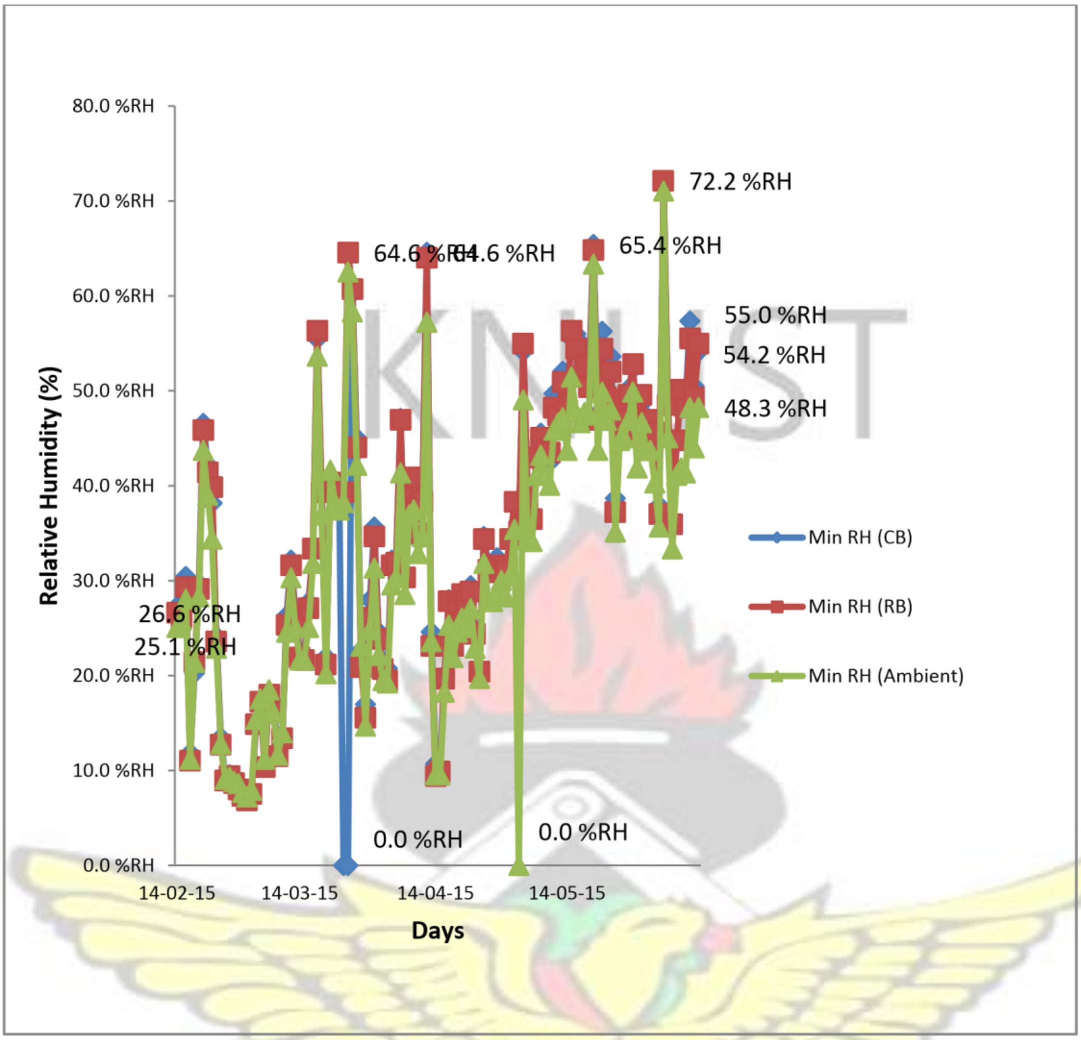

Figure 20: Daily minimum relative humidity inside and ambient of the Barns

4.1.5.2 Maximum relative humidity in the day

Maximum relative humidity in the circular barn ranged between 17.7-100 %, the rectangular barn ranged between 17.8-100 % and the ambient range was18.5-100 % (figure 21).

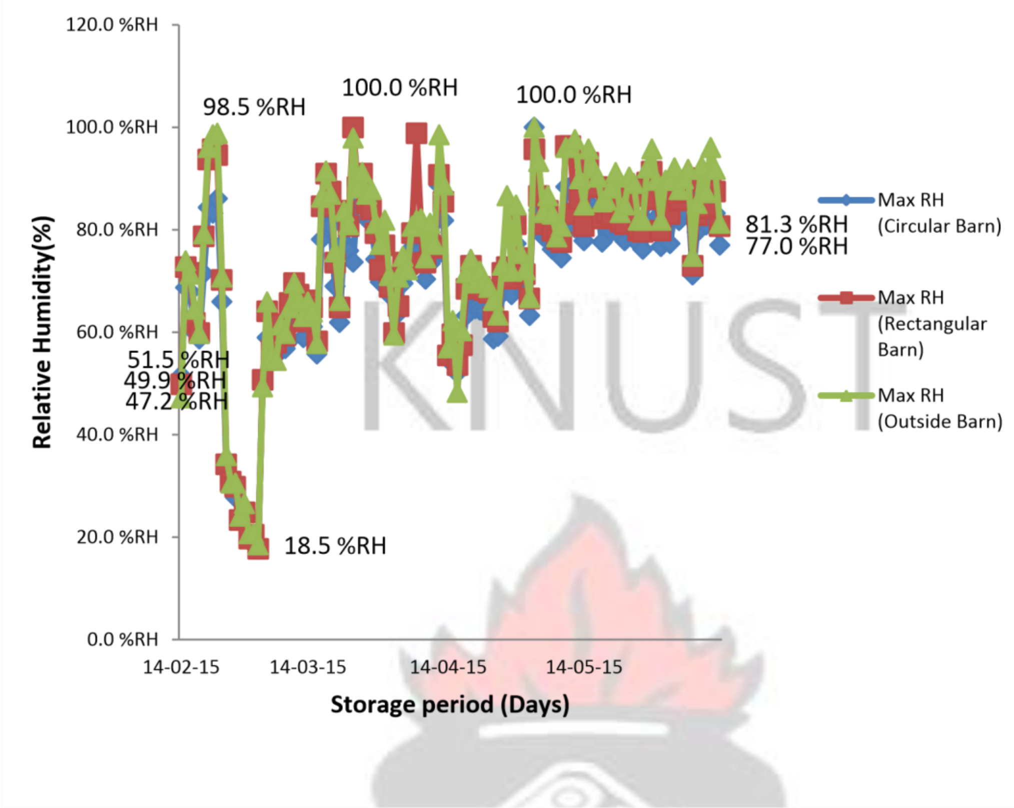

Figure 21: Daily maximum relative humidity within and outside the barn

4.1.6 Average monthly readings of temperature and relative humidity

Average monthly figures for temperature, relative humidity, sprouts, rotting, weight loss, sprouts weight, rodent attack have been presented in Tables 3 and 4.

Table 3: Average temperature and relative humidity

structure	Average Temperature (°C)			Average Relative Humidity (%)		
	Max	Min	Average	Max	Min	Average
Circular barn	39.4	21.5	30.6	100	0.0	52.1
Rectangular barn	43.5	21.2	31.1	100	6.8	53.7
Ambient	45.6	21.1	31.8	100	0.0	53.4

Table 4: Average monthly sprouts, rotting, weight loss, sprouts weight, rodent attack

Structure	Cultivars	Sprouts	Rotting (%)	Weight loss(%)	Sprout Weight (%)	Rodent attack
Circular barn	*Pona*	31.5	4.2	7.1	2.10	nil nil
	Afebetoyen	50.8	1.3	7.8	0.94	
Rectangular barn	*Pona*	57	1.7	8.9	2.10	nil
	Afebetoyen	51	2.10	8.9	1.20	nil

4.1.6 Condition of tubers in the circular barn with respect to sprout, rotting, weight loss, sprout weight and pest/rodent attack

4.1.6.1 Sprouting

Table 5: Means on rate of sprouting

Cultivar	B_1	B_2	B_3	B_4	LSD(0.05)
Pona	0.1700	0.1775	0.2350	0.1725	0.05669
Afebetoyen	0.1400	0.1500	0.1325	0.1575	0.03192

From Table 5 there was significant difference in sprout among the *Pona* sample groups (B_3, >B_1, B_2, B_4) with the least significant difference (LSD) of 0.05669.in the circular barn. However, there was no statistically difference between sample groups of *Afebetoyen*.

4.1.6.2 Tuber rot

Table 6: Means of tubers rot

Cultivar	B_1	B_2	B_3	B_4	LSD(0.05)
Pona	0.000	0.048	0.115	0.000	0.1283
Afebetoyen	0195	0.000	0.000	0.098	0.2295

There was not significant difference in tuber rot among the samples (B_1, B_2, B_3 and B_4) in the circular barn for both *Pona* and *Afebetoyen cultivars* during storage period. The LSD for *Pona* was 0.1283 and 0.2295 for *Afebetoyen* in the circular barn. Therefore, losses due to tuber rot were not significantly different between samples in the barns (Table 6).

4.1.6.3 Weight loss

For the entire storage period, no significant difference ($p>0.05$) observed between the samples (B_1, B_2, B_3 and B_4) in both *Pona* and *Afebetoyen*. *Pona* had LSD of 0.698 while *Afebetoyen* had LSD of 1.471. It was observed that, there was no significant difference in weight loss among cultivars in the circular barn (Table 7).

Table 7: Means on Weight loss among sample groups

Cultivar	B_1	B_2	B_3	B_4	LSD(0.05)
Pona	0.65	0.57	0.45	0.67	0.698
Afebetoyen	0.36	1.10	1.19	0.38	1.471

4.1.6.4 Sprout weight of tubers

There was a significant difference ($p<0.05$) between sprout weight of samples of *Pona* ($B_4 > B_1$ and B_2), but not group B_3 at LSD of 0.3977. However, there was no difference between sprout weights of *Afebetoyen* at LSD of 0.5956 as shown in Table 8.

Table 8: Means of sprout weight

Cultivar	B_1	B_2	B_3	B_4	LSD (0.05)
Pona	0.547	0.718	0.917	1.138	0.3977
Afebetoyen	1.055	1.397	0.912	1.465	0.5956

4.1.6.5 Pest/Rodents Attack

No rodent attack was recorded throughout the storage period. This meant that, the barns were resistant to pest and rodent attacks.

4.1.7 Condition of tubers in the rectangular barn with respect to sprouts, rotting, weight loss, sprouts weight and pest/rodents attack.

4.1.7.1 Sprout

Unlike the groups in the circular barn, those in the rectangular barn recorded no significant differences ($p>0.05$) among groups (B_1, B_2, B_3 and B_4) for both *Pona* and *Afebetoyen*. *Pona* had LSD of 0.06025. *Afebetoyen* also had LSD of 0.04519. None of sampled groups recorded any significant difference throughout the storage period (Table 9)

Table 9: Means of sprouts of tubers

Cultivar	B_1	B_2	B_3	B_4	LSD(0.05)
Pona	0.1225	0.1550	0.1375	0.550	0.06025
Afebetoyen	0.1625	0.1325	0.1350	0.1575	0.04519

4.1.7.2 Tuber Rot

Just like in the circular barn, there were no significant difference ($p>0.05$) on tuber rot among the samples (B_1, B_2, B_3 and B_4) in the rectangular barn. LSD for *Pona* was 0.2365. *Afebetoyen* also recorded no significant difference ($p>0.05$) with an LSD of 0.2802 (Table 10).

Table 10: Means of tubers rot in the rectangular barn

Cultivar	B_1	B_2	B_3	B_4	LSD(0.05)
Pona	0.000	0.068	0.098	0.098	0.2365
Afebetoyen	0.098	0.068	0.098	0.098	0.2802

4.1.7.3 Weight loss during storage

Both *Pona* and *Afebetoyen* in the rectangular barn did not record any significant difference ($p>0.05$) among the samples (B_1, B_2, B_3 and B_4) for the storage period. *Pona* had LSD of 0.1869 while *Afebetoyen* had LSD of 0.3856 (Table 11).

Table 11: Weight loss by tubers during storage

Cultivar	B_1	B_2	B_3	B_4	LSD(0.05)
Pona	0.407	0.400	0.352	0.335	0.1869
Afebetoyen	0.355	0.358	0.318	0.575	0.3856

4.1.7.4 Sprout weight

Sprouts weight were not statistically different ($p>0.05$) in both *Pona* and *Afebetoyen.* *Pona* had LSD of 0.926 while *Afebetoyen* had LSD had 0.704 (Table 12).

Table 12: Mean of sprout weight in rectangular barn

Cultivar	B_1	B_2	B_3	B_4	LSD(0.05)
Pona	1.18	0.70	1.12	1.17	0.926
Afebetoyen	1.12	1.21	0.98	1.26	0.704

4.1.7.5 Pest/Rodent Attack

Just like the circular barn no rodent attack was recorded in the rectangular barn. This meant that, tubers had a100 percent protection against rodents or termite infestation.

4.1.8 Effects of storage barns on tuber shelf life

The two interventions adopted for the study performed almost equally and were able to keep tubers for at least 4 months (118 days) without significant rotting. Tuber samples were stored for a period of four months (118 days). However, *Pona* recorded

3.3 % rot in the second month. *Afebetoyen* performed better in the circular barn with an average rot of 1.6 % while *Pona* recorded an average rot of 13.4 % in the same barn. However, in the rectangular barn, the two cultivars (*Pona* and *Afebetoyen*) did not record significant different (p> 0.05) because, in the fourth month both recorded 6.6% as shown in Figure 22.

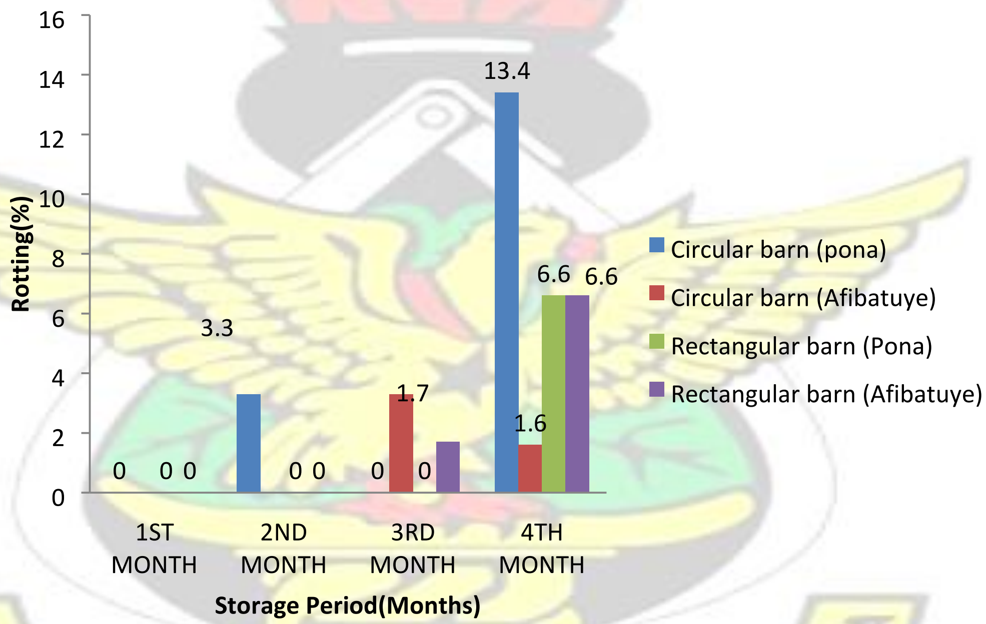

Figure 22: Effects of storage barns on tuber shelf life

4.1.9 Effects of stored methods on dormancy

Both the circular and rectangular barns showed little impact on tuber dormancy throughout the period since percentage of sprouts in both storage barns was quite high.

Averagely, *Pona* recorded the lowest sprouting of 23.3 % compared to *Afebetoyen* which recorded 61.7 % in the first month.

From Figure 23, it is shown that the circular barn suppressed sprouting of tubers better than the rectangular barn. In the rectangular barn, *Pona* did not record significant difference (p<0.05) from *Afebetoyen*. Both recorded higher percentage in sprouts with 76.7 % and 58.4 % for *Pona* and *Afebetoyen* in the fourth month (figure 23).

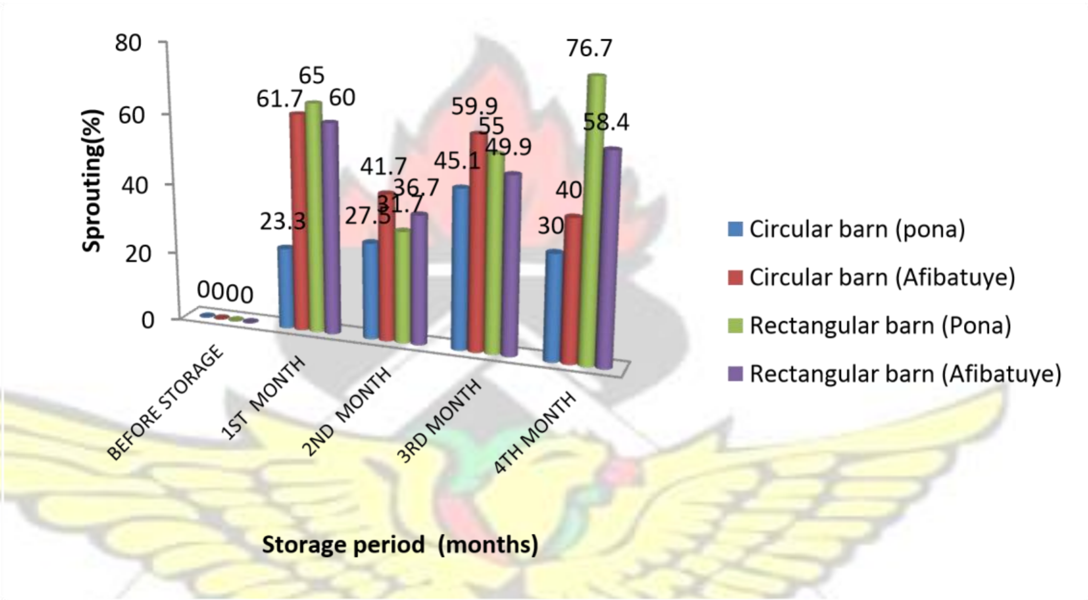

Figure 23: Effects of storage barns on tuber dormancy

4.1.10 Benefit and loss analysis with respect to weight loss in storing tubers

The price of tubers of yam largely depends on their weight and how fresh it looks. Consumers fall on these two factors before buying. Weightless and wrinkled tubers are always sold at very low prices.

Therefore, these two factors must always be taken into consideration during storage to avoid unnecessary losses. Effects of these were observed during the experiment and it was realized that, farmers adopting this intervention should, at least, sell the stored tubers 3-4 months after storage in order to break even. It was realized that, after this period, tubers lost their weights significantly cumulatively, up to above 35 % in some cases and also began to shrink (Figure 24).

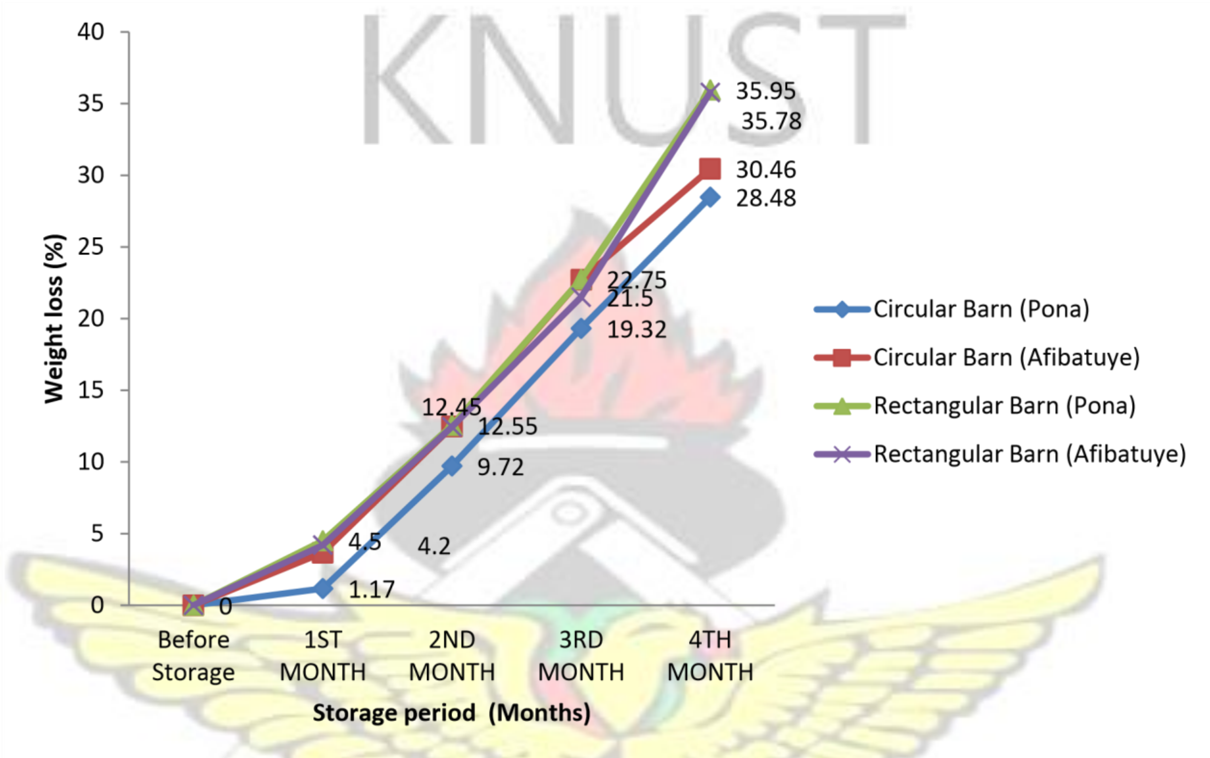

Figure 24: Benefit and loss analysis with respect to weight loss

4. 2 Discussions

4.2.1 Effect of storage barns on temperature and relative humidity

Temperatures within and outside the two storage barns were monitored throughout the study period with the use of loggers. Readings started on 14th February, 2015 and ended on the 13th June, 2015. The loggers were programmed to take hourly readings which read 2832 times for a period of 118 days.

4.2.2 Temperature

Temperatures recorded in the circular barn fluctuated from a minimum of 21.5 °C to a maximum of 39.4 °C with an average temperature of 30.6 °C. The rectangular barn recorded a minimum temperature of 21.2 °C and maximum temperature of 43.5 °C with an average temperature of 31.1°C. The ambient recorded a minimum temperature of 21.1 °C and a maximum temperature of 45.6 °C with the average being 31.8 °C.

The temperatures in the three environments were statistically not different ($p>0.05$) from one another. However, averagely the values were higher than recommended storage temperature of 26-28 °C which can be assumed typical for West Africa (Demeaux and Vivier, 1984). This temperature can be reduced by planting trees around the structures..

4.2.3 Relative humidity

The circular barn recorded minimum relative humidity of 0.0 % on 24th and 25th March, 2015 due to rain shower on those days. Also, the maximum relative humidity recorded was 100 % on 3rd May, 2015 which was sunny day. The average relative humidity recorded was 52.1 %. The rectangular barn recorded minimum of 6.8 % relative humidity and Maximum of 100 % on the same date 3rd May, 2015. Averagely, it recorded 53.7 % relative humidity. The ambient also recorded a minimum relative humidity of 0.0 % and a Maximum of 100 % with the average of

50.9 % on 3rd May, 2015. The minimum relative humidity recorded was on 38th and 39th day after storage and maximum was on 78th day after storage.

4.2.4 Sprouting

Results obtained revealed that, *Pona* showed more resistance to sprouting better than *Afebetoyen* in the circular barn as it recorded an average of 31.5% sprouts compared to *Afebetoyen* which recorded averagely 50.8% sprouts in the same circular barn.

In another vein, sprouts of *Pona* in the rectangular barn were higher than *Afebetoyen*. Averagely, it recorded 57% while *Afebetoyen* recorded 51%.

Sprouting was generally high in both barns and it significantly contributed to weight loss during storage by turning the edible tuber carbohydrates to inedible sprout and desiccation (Osunde, 2008; Imeh *et al*., 2012).

This meant that, *Pona* performed better in the circular barn with 31.5 % sprout compared to rectangular barn which recorded 57 % sprout (Table 4).

4.2.5 Tuber rot

The *Afebetoyen* cultivar showed a high resistance to rotting than the *Pona*, it recorded an average of 1.30 % rot lower than *Pona*, which recorded 4.2 % under the same condition (Table 4). However, the rectangular barn recorded the reverse. *Pona* recorded the lowest with average readings of 1.7 % against *Afebetoyen* which recorded 2.1 % rotting. Therefore, there was no statistical difference (5 %) between the two barns in terms of tuber not.

4.2.6 Weight loss

The results on the weight loss indicated that, there were no clear difference between *Pona* and *Afebetoyen* cultivar in both barns. *Pona* recorded an average monthly weight loss of 7.1 % and *Afebetoyen* recorded 7.8 % in the circular barn under the same condition. For the rectangular barn, both *Pona* and *Afebetoyen* recorded 8.9 %.

Therefore, there was no significance different in weight loss of the tuber between the barns (Table 4).

4.2.7 Sprout weight

According to Adeyinka *et al.*, (2011), sprouts contribute to tuber weight loss by increasing transpiration rate of tubers and this has been confirmed during the study. Averagely, sprouts contributed 2.1 % weight loss monthly to *Pona* in both barns. On the other hand, *Afebetoyen* recorded 0.94 % in the circular barn and 1.2 % in the rectangular barn. There were, however, no statistical different, between *Pona* and *Afebetoyen* sprouts (Table 4).

4.2.8 Pest/rodent attacks

Throughout the study period, there was no recorded incident of pest/rodent attacks on both cultivars in the two barns (Tables 4). The stored tubers were 100 % protected from pests/rodents. This might be due to the materials used in the construction of the barn especially the stand where teak was used. It is known to be a strong material which is resistant to termite attack. Also, rodent guards were fixed on the columns to prevent rodents such as mice/rats from climbing.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The study showed that, on the average, temperature of 30.6 °C and relative humidity 52.1 % in the circular barn were lower than that recorded in the rectangular barn which recorded 31.1 °C temperature and 53.1%.. Ambient conditions were recorded 31.8 °C for temperature and 53.4 % for relative humidity. However, there was no significant difference in temperature and relative humidity in both barns.

Sprouting was generally high in both barns. Both barns recorded above 50 % sprouts. Averagely, the lower value was 31.5 % was recorded for *Pona* in the circular barn. Therefore, there was significant difference between the two barns. Sprout recorded was high throughout the period in both *Pona* and *Afebetoyen* and high percent of sprouting indicated low influence of barn on dormancy.

The level of rot was not significantly different between the two barns. There was generally low percentage of rot recorded. Both barns can store yams for at least four months.

There was no significant weight loss among the two cultivars. However, the circular barn suppressed rate of weight loss as compared to the rectangular barn. *Pona* recorded a lower weight loss of 7.1% averagely and this confirmed the work of Addae (2013) who reported that *Pona* cultivar often retained significantly, a better weight throughout storage.

Pest/rodent attack records from the study revealed that both storage methods performed excellently in pest/rodent control. There was no recorded incident throughout the storage period.

However, it was observed that, *Afebetoyen* could withstand the condition because; tuber rot was lower compared to *Pona*. It did not also shrink as much as compared to *Pona*.

5.2 Recommendations

From the result of the study, both storage barns are good for yam storage. This is because, both barns were able to keep tubers in better condition throughout the period even though, temperature and relative humidity were quite high. Tuber rot was very minimal and no rodent attack was recorded.

Materials for the barns construction can be acquired locally and relatively low or no cost. The barns can accommodate large numbers of tubers. They are durable if good care is taken. It is also the surest method for protecting tubers from the rap of the sun and rain and also protecting tubers against theft since the barns can be locked.

The barns are well ventilated and non-conductor of heat especially, during the hottest time of the year. They can easily be constructed by local artisans and, above all, the barns are excellent in controlling pest/rodent attack.

Both barns can be used for yam storage and the choice of shape is left of ease of construction by artisans.

Local materials can be used for the construction and costs can be low.

Cooler temperatures afforded by the materials of construction would enable better and longer storage periods.

It is however recommended that, the following areas can be looked at in further research:

- cost benefit analysis of the two improved structures
- Other yam cultivars can be used for research and
- Lifespan and capacity of the structures

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APPENDICES

Appendix 1: Analysis of Variance in circular barn

1.1 Analysis of variance tables for Pona cultivar

Analysis of variance table for Sprouting

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	0.0014500	0.0004833	1.13	0.377
Residual	12	0.0051500	0.0004292		
Total	15	0.0066000			

Grand mean 0.1450

Analysis of variance table for Rotting

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	0.10457	0.03486	1.57	0.248
Residual	12	0.26617	0.02218		
Total	15	0.37074			

Grand mean 0.073

Analysis of variance table for Weight loss

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	2.4350	0.8117	0.89	0.474
Residual	12	10.9375	0.9115		
Total	15	13.3726			

Grand mean 0.76

Analysis of variance table for Sprouts weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	0.8508	0.2836	1.90	0.184
Residual	12	1.7936	0.1495		
Total	15	2.6443			

Grand mean 1.208

Analysis of variance table for Rodent/Pest attack

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	0.	0.		
Residual	12	0.	0.		

Total	15	0.

Grand mean 0.00

1.2 Analysis of variance table for *afebetoyen* cultivar

Analysis of variance table for sprouting

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	0.0014500	0.0004833	1.13	0.377
Residual	12	0.0051500	0.0004292		
Total	15	0.0066000			

Grand mean 0.1450

Analysis of variance table for Rotting

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	0.10457	0.03486	1.57	0.248
Residual	12	0.26617	0.02218		
Total	15	0.37074			

Grand mean 0.073

Analysis of variance table for weight loss

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	2.4350	0.8117	0.89	0.474
Residual	12	10.9375	0.9115		
Total	15	13.3726			

Grand mean 0.76

Analysis of variance table for Sprouts weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	0.8508	0.2836	1.90	0.184
Residual	12	1.7936	0.1495		
Total	15	2.6443			

Grand mean 1.208

Analysis of variance table for Rodents/Pest Attacks

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	0.	0.		
Residual	12	0.	0.		
Total	15	0.			

Grand mean 0.00

Appendix 2: Analysis of Variance in Rectangular Barn

2.1 Analysis of variance tables for Pona cultivar

Analysis of variance table for Sprouting

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	0.002950	0.000983	0.64	0.602
Residual 12 0.018350 Total			15 0.001529		
0.021300					

Grand mean 0.1425

Analysis of variance table for Rotting (Decay)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	0.02537	0.00846	0.36	0.784
Residual 12 0.28283 Total	15	0.30819	0.02357		

Grand mean 0.066

Analysis of variance table for Weight loss

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	0.01513	0.00504	0.34	0.795
Residual 12 0.17665 Total	15	0.19178	0.01472		

Grand mean 0.374

Analysis of variance table for Sprouts weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	0.6423	0.2141	0.59	0.632
Residual	12	4.3369	0.3614		
Total	15	4.9792			

Grand mean 1.05

Analysis of variance table for Rodents/Pest Attacks

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	0.	0.		
Residual	12	0.	0.		
Total	15	0.			

Grand mean 0.00

2.2 Analysis of variance tables for *afebetoyen* cultivar

Analysis of variance table for Sprouting

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	0.0028188	0.0009396	1.09	0.390
Residual	12	0.0103250	0.0008604		
Total	15	0.0131438			

Grand mean 0.1469

Analysis of variance table for rotting

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	0.00270	0.00090	0.03	0.994
Residual	12	0.39690	0.03308		
Total	15	0.39960			

Grand mean 0.090

Analysis of variance table for Weight loss

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	0.16503	0.05501	0.88	0.480
Residual 12 0.75155 Total	15	0.91658	0.06263		

Grand mean 0.401

Analysis of variance table for Sprouts weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	0.2577	0.0859	0.41	0.748
Residual 12 2.5049 Total	15	2.7626	0.2087		

Grand mean 1.19

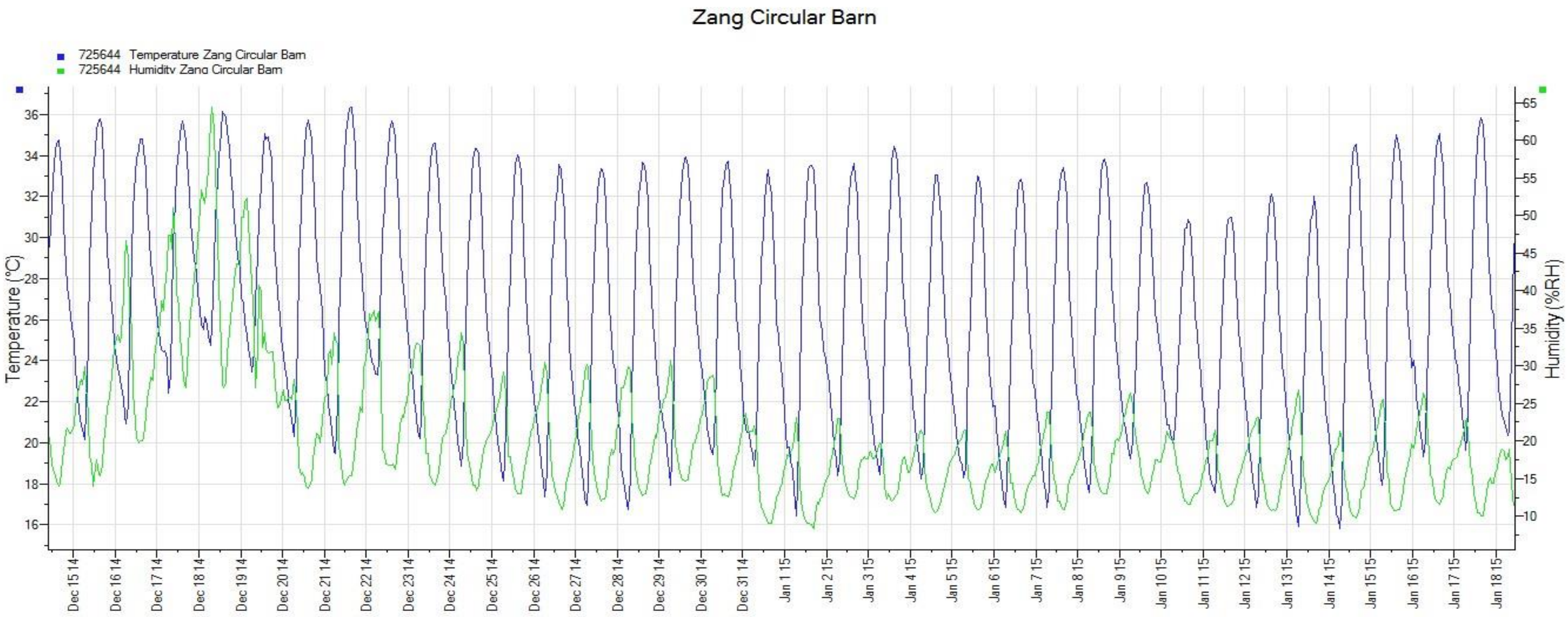
Analysis of variance table for Rodents/Pest Attacks

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	3	0.	0.		
Residual 12 0. Total 15 0.			0.		

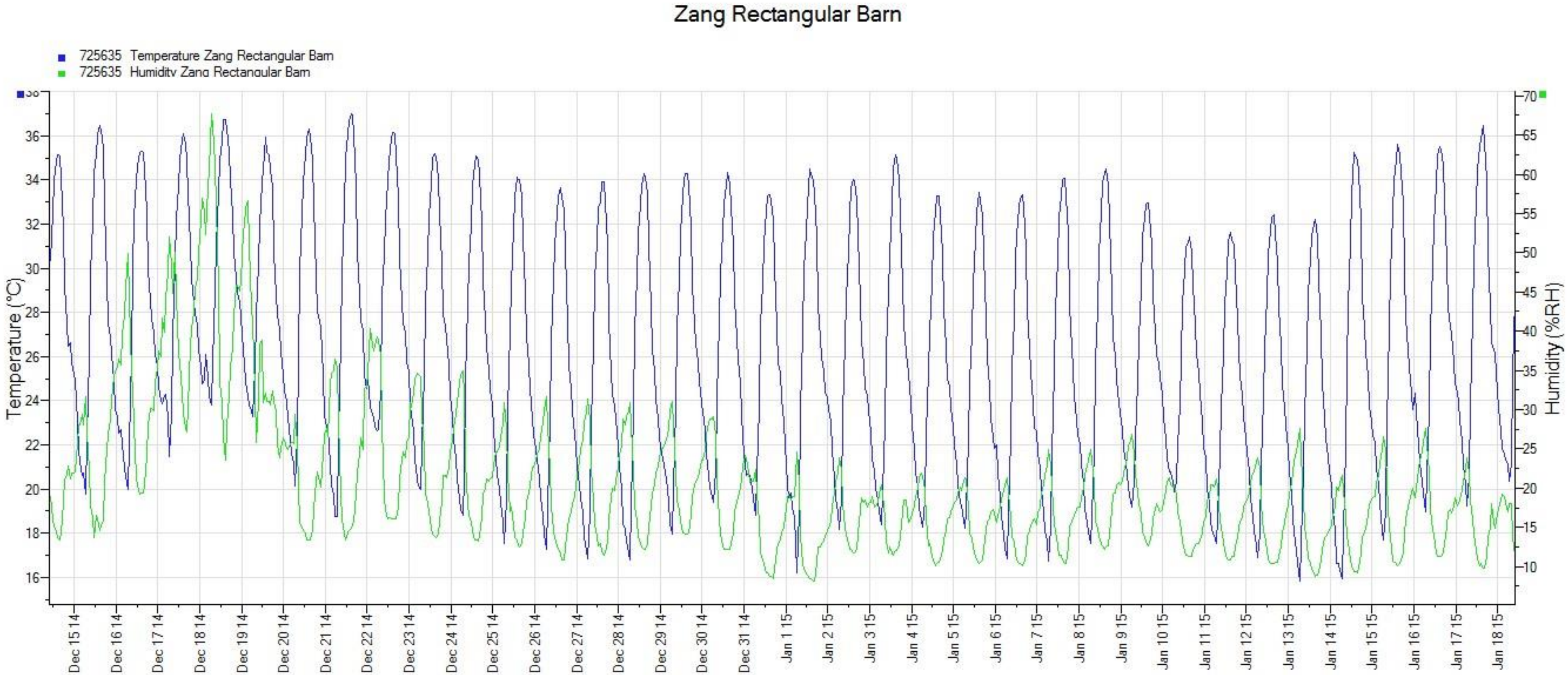
Grand mean 0.00

Appendix 2: Daily Pre-Storage Temperatures (°C) and Relative Humidity (%) during Storage period 2.1

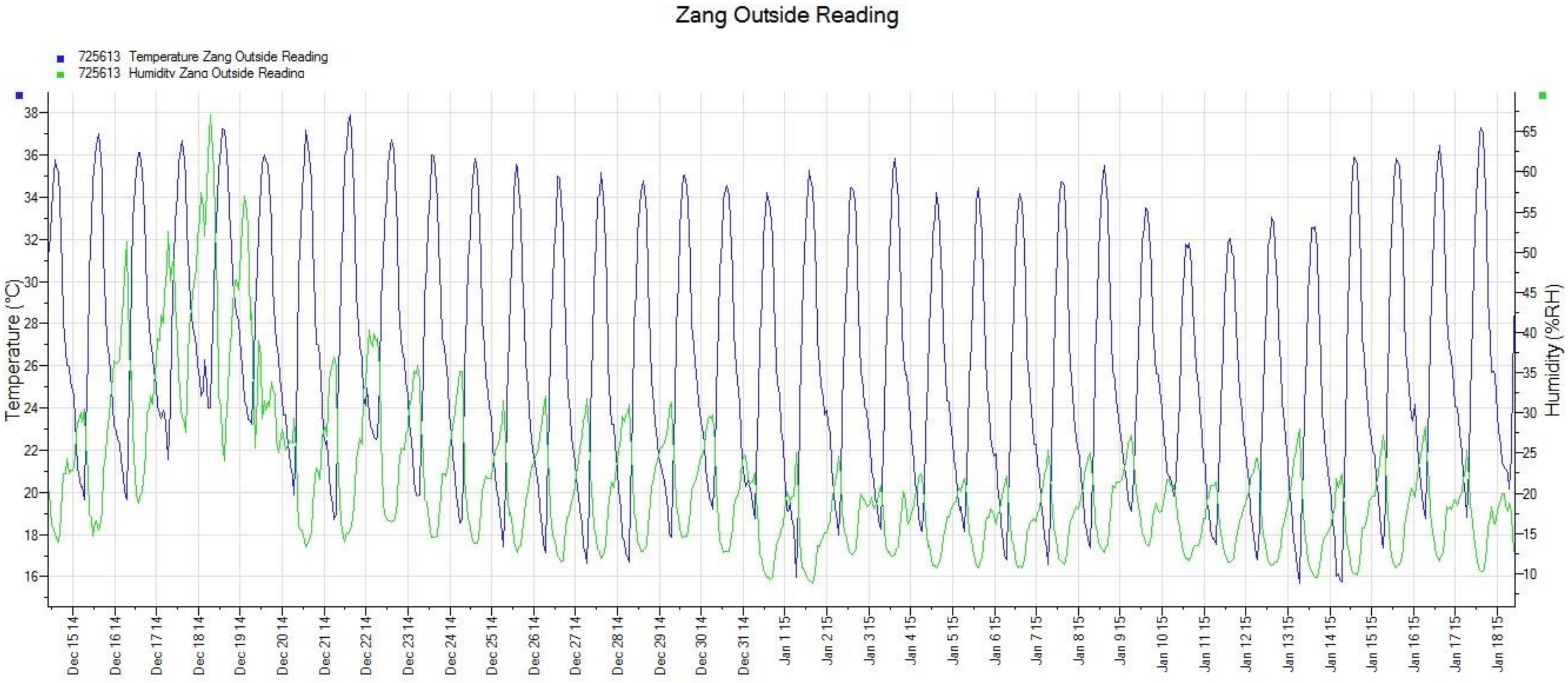
Pre-Storage Temperatures (°C) and Relative Humidity (%) in the Circular Barn



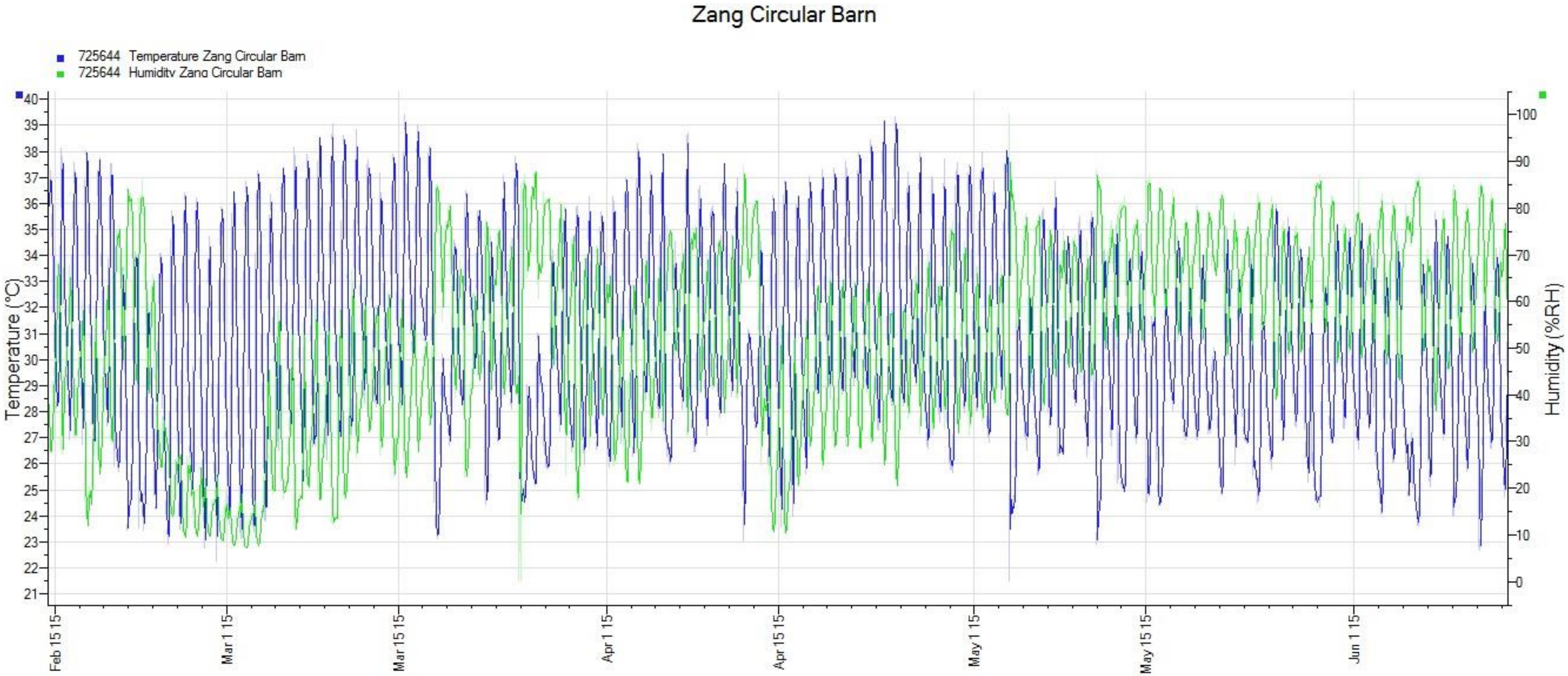
2.2 Pre-Storage Temperatures(°C) and Relative Humidity (%) in the Rectangular Barn



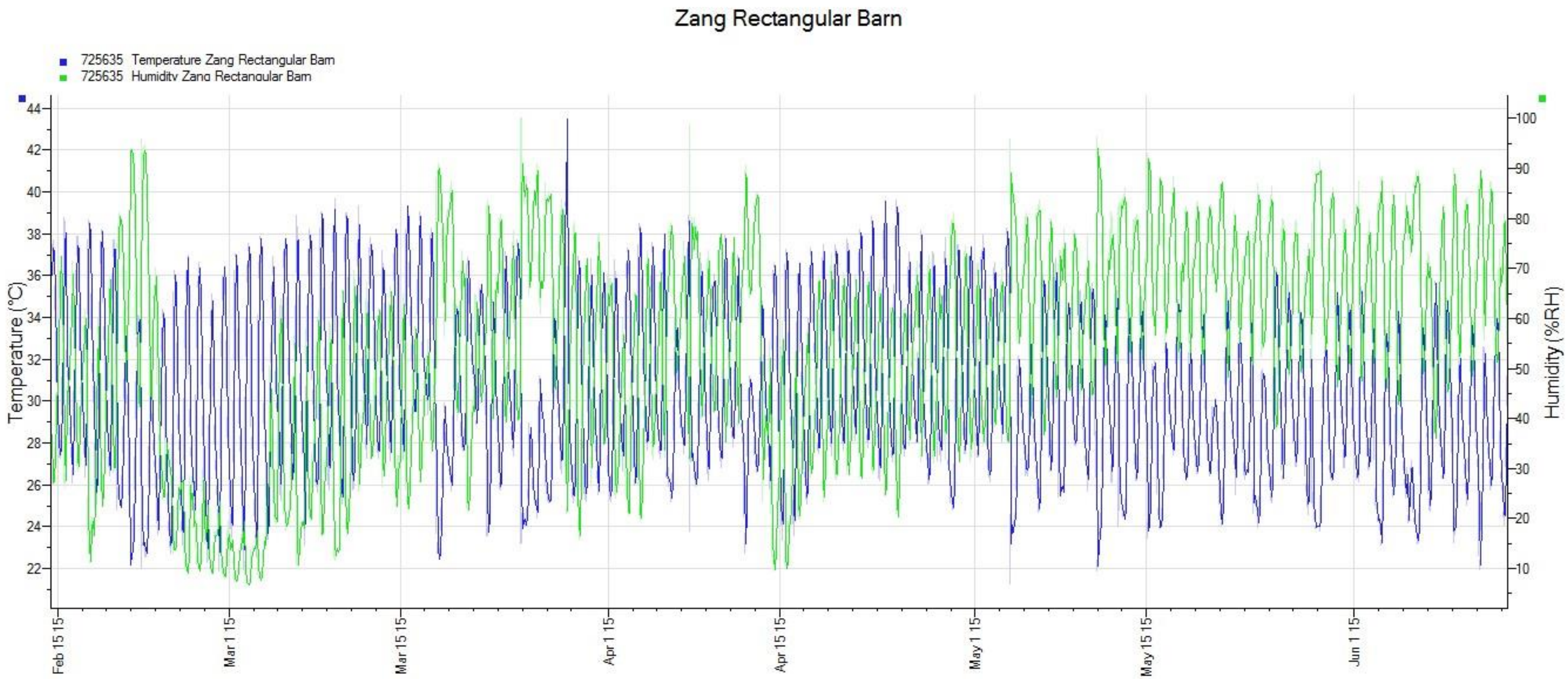
2.3 –Pre-Storage Temperatures(ºC) and Relative Humidity (%) in the outside of the two barns(Ambient)



2.4 Daily Temperature (^{o}C) and Relative Humidity (%) in the Circular Barn During storage



2.5 Daily Temperature (ºC) and Relative Humidity (%) in the Rectangular Barn during storage


Zang Rectangular Barn
725635 Temperature Zang Rectangular Barn
725635 Humidity Zang Rectangular Barn
Temperature (°C)
Humidity (%RH)
44
42
40
38
36
34
32
30
28
26
24
22
100
90
80
70
60
50
40
30
20
10
Feb 15 15
Mar 1 15
Mar 15 15
Apr 1 15
Apr 15 15
May 1 15
May 15 15
Jun 1 15

2.6.Daily Temperature (°C) and Relative Humidity (%) outside the Barns during storage

Appendix 3.0 PARAMETERS READ IN THE TWO STRUCTURES DURING STORAGE

3.1.1 PONA

SPROUTING

		% OF SPROUTING				
SAMPLES	BEFORE STORAGE	1ST MONTH	2ND MONTH	3RD MONTH	4TH MONTH	AVERAGE %
B1	0	20	30	67	40	39.3
B2	0	20	33.3	40	40	33.3
B3	0	13.3	13.3	40	13.3	20
B4	0	40	33.3	33.3	26.7	33.3

ROTTING

		% ROTTING				
SAMPLES	BEFORE STORAGE	1ST MONTH	2ND MONTH	3RD MONTH	4TH MONTH	AVERAGE %
B1	0	0	0	0	0	0
B2	0	0	0	0	26.7	6.7
B3	0	0	13.3	0	26.7	10
B4	0	0	0	0	0	0

WEIGHT LOSS

		% OF WEIGHT LOSS				
SAMPLES	BEFORE STORAGE	1ST MONTH	2ND MONTH	3RD MONTH	4TH MONTH	AVERAGE %
B1	0	2.6	6.8	9.9	0.6	5
B2	0	0.5	9.2	10.2	16.7	9.2
B3	0	0.98	14.3	13.8	13.3	10.6
B4	0	0.6	3.9	4.5	6	3.8

SPROUTS WEIGHT

		% OF SPROUTS WEIGHT				
SAMPLES	BEFORE STORAGE	1ST MONTH	2ND MONTH	3RD MONTH	4TH MONTH	AVERAGE %
B1	0	2.6	2.8	2.8	6.3	3.6
B2	0	2.7	3	3.3	0.8	2.5
B3	0	0.99	1.7	1.7	0.8	1.3
B4	0	0.5	0.6	0.6	3.2	1.2

PEST/RODENTS ATTACK

		% RODENT ATTACK				
SAMPLES	BEFORE STORAGE	1ST MONTH	2ND MONTH	3RD MONTH	4TH MONTH	AVERAGE %
B1	0	0	0	0	0	0
B2	0	0	0	0	0	0
B3	0	0	0	0	0	0
B4	0	0	0	0	0	0

2.1 CIRCULAR BARN

		% OF SPROUTING				
SAMPLES	BEFORE STORAGE	1ST MONTH	2ND MONTH	3RD MONTH	4TH MONTH	AVERAGE %
B1	0	53.3	53.3	66.6	40	53.3
B2	0	53.3	33.3	60	40	46.7
B3	0	73.3	46.7	66.6	53.3	60
B4	0	66.7	33.3	46.7	26.7	43.4

DECAY/ROTTING

		% ROTTING				
SAMPLES	BEFORE STORAGE	1ST MONTH	2ND MONTH	3RD MONTH	4TH MONTH	AVERAGE %
B1	0	0	0	6.6	6.6	3.3
B2	0	0	0	0	0	0
B3	0	0	0	0	0	0
B4	0	0	0	6.7	0	1.7

WEIGHT LOSS

		% OF WEIGHT LOSS				
SAMPLES	BEFORE STORAGE	1ST MONTH	2ND MONTH	3RD MONTH	4TH MONTH	AVERAGE %
B1	0	5.5	5.8	11.1	11.7	8.5
B2	0	2.7	9.9	10.2	8.6	7.9
B3	0	1.4	9.9	9.4	5.2	6.5
B4	0	5.1	9.5	10.4	5	7.5

SPROUTS WEIGHT

		% OF SPROUTS WEIGHT				
SAMPLES	BEFORE STORAGE	1ST MONTH	2ND MONTH	3RD MONTH	4TH MONTH	AVERAGE %
B1	0	1.4	0.9	0.7	0.8	0.9
B2	0	0.3	0.3	0.7	1.9	0.8
B3	0	1.4	0.9	1	1.8	1.3
B4	0	0.5	0.3	0.3	1.8	0.7

PEST/RODENTS ATTACK

		% RODENT ATTACK				
SAMPLES	BEFORE STORAGE	1ST MONTH	2ND MONTH	3RD MONTH	4TH MONTH	AVERAGE %
B1	0	0	0	0	0	0
B2	0	0	0	0	0	0
B3	0	0	0	0	0	0
B4	0	0	0	0	0	0

3.1.2. AFEBETOYEN

SPROUTING

3.2 RECTANGULAR BARN

3.2.1. PONA

SPROUTING

		% OF SPROUTING				
SAMPLES	BEFORE STORAGE	1ST MONTH	2ND MONTH	3RD MONTH	4TH MO TH	% AVERAGE
B1	0	66.7	60	73.3	73.3	68.3
B2	0	60	20	40	80	50
B3	0	53.3	26.7	66.7	93.3	60
B4	0	80	20	40	60	50

ROTTING

		% ROTTING				
SAMPLES	BEFORE STORAGE	1ST MONTH	2ND MONTH	3RD MONTH	4TH MONTH	% AVERAGE
B1	0	0	0	0	0	0
B2	0	0	0	0	13.3	3.3
B3	0	0	0	0	6.6	1.7

B4	0	0	0	0	6.7	1.7

WEIGHT LOSS

		% OF WEIGHT LOSS				
SAMPLES	BEFORE STORAGE	1ST MONTH	2ND MONTH	3RD MONTH	4TH MONTH	% AVERAGE
B1	0	2.4	10	11.1	7.8	7.8
B2	0	3.8	3.2	9.3	25	10.3
B3	0	5.9	9.7	9.9	7.7	8.3
B4	0	5.9	9.3	10.5	12.3	9.5

SPROUTS WEIGHT

		% OF SPROUTS WEIGHT				
SAMPLES	BEFORE STORAGE	1ST MONTH	2ND MONTH	3RD MONTH	4TH MONTH	% AVERAGE
B1	0	2.5	0.3	0.3	5.1	2.1
B2	0	3.9	2.8	0.6	6.3	3.4
B3	0	0.6	0.7	0.5	2.8	1.2
B4	0	0.8	0.2	1.2	5.3	1.9

SPROUTS WEIGHT

PEST/RODENTS ATTACK

		% RODENT ATTACK				
SAMPLES	BEFORE STORAGE	1ST MONTH	2ND MONTH	3RD MONTH	4TH MONTH	% AVERAGE
B1	0	0	0	0	0	0
B2	0	0	0	0	0	0
B3	0	0	0	0	0	0
B4	0	0	0	0	0	0

3.2.2 AFEBETOYEN

SPROUTING

	% OF SPROUTING

SAMPLES	BEFORE STORAGE	1ST MONTH	2ND MONTH	3RD MONTH	4TH MONTH	% AVERAGE
B1	0	40	20	53.3	60	43.3
B2	0	66.7	33.3	60	80	60
B3	0	73.3	40	53.3	66.7	58.3
B4	0	60	53.3	33.3	26.7	43.3

ROTTING

		% ROTTING				
SAMPLES	BEFORE STORAGE	1ST MONTH	2ND MONTH	3RD MONTH	4TH MONTH	% AVERAGE
B1	0	0	0	0	6.7	1.7
B2	0	0	0	0	13.3	3.3
B3	0	0	0	6.7	0	1.7
B4	0	0	0	0	6.7	1.7

WEIGHT LOSS

		OF WEIGHT LOSS				
SAMPLES	BEFORE STORAGE	1ST MONTH	2ND MONTH	3RD MONTH	4TH MONTH	% AVERAGE
B1	0	5	7.3	8.2	15.9	9.1
B2	0	3.7	8.9	9.7	15.4	9.4
B3	0	7.5	9.5	10.4	13.3	10.2
B4	0	0.6	7.3	7.9	12.5	7.1

SPROUTS WEIGHT

		% F SPROUTS WEIGHT				
SAMPLES	BEFORE STORAGE	1ST MONTH	2ND MONTH	3RD MONTH	4TH MONTH	% AVERAGE
B1	0	0.5	0.3	0.6	1.9	0.8
B2	0	0.5	0.3	0.9	3.6	1.3
B3	0	0.8	0.6	1	3.8	1.6
B4	0	0.6	0.3	0.7	2	0.9

PEST/RODDENT ATTACK

	RODENT ATTACK

SAMPLES	BEFORE STORAGE	1ST MONTH	2ND MONTH	3RD MONTH	4TH MONTH	% AVERAGE
B1	0	0	0	0	0	0
B2	0	0	0	0	0	0
B3	0	0	0	0	0	0
B4	0	0	0	0	0	0