UNIVERSITY FOR DEVELOPMENT STUDIES

EVALUATION OF SHELF-LIFE AND NUTRITIONAL CHARACTERISTICS OF SEVEN YAM ACCESSIONS IN NORTHERN GHANA

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2022

UNIVERSITY FOR DEVELOPMENT STUDIES

FACULTY OF AGRICULTURE, FOOD AND CONSUMER SCIENCES

DEPARTMENT OF HORTICULTURE

EVALUATION OF SHELF-LIFE AND NUTRITIONAL CHARACTERISTICS OF SEVEN YAM ACCESSIONS IN NORTHERN GHANA

BY

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THESIS SUBMITTED TO THE DEPARTMENT OF HORTICULTURE,

FACULTY OF AGRICULTURE, FOOD AND CONSUMER SCIENCE,

UNIVERSITY FOR DEVELOPMENT STUDIES IN PARTIAL FULFILLMENT

OF THE REQUIREMENT FOR THE AWARD OF MASTER OF SCIENCE

DEGREE IN HORTICULTURE SCIENCE.

DECEMBER, 2022

DECLARATION

I hereby declare that, except for references which have been duly cited as a source of information in this thesis, is the result of my original work and no part of it has been used for another degree in this University or elsewhere.

MASAUDI HARRIETA ……. …….

(STUDENT) SIGNATURE DATE

I hereby declare that the preparation and the presentation of the thesis was supervised in accordance with the guidelines on supervision laid down by the University for Development Studies.

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ABSTRACT

Yam (*Dioscorea* spp.) is a major tuber crop that serves as a staple for thousands of households particularly in the developing world. In Ghana, yam is major source of dietary energy to many households, and contributes to food security and income to many families; particularly in northern Ghana. In spite of the massive contribution of yam to the socio-economic development of Ghana, yam producers have over the years struggled with storage issues which often result in postharvest losses. Due to the rainfall pattern, yam is cultivated seasonally but consumed all year round, suggesting proper storage methods are necessary to promote all-year-round availability. Currently, farmers depend on traditional methods of storing yam which is associated with varying degrees of postharvest losses. As a result, postharvest losses have been highlighted as a major problem facing the actors (farmers, buyers and consumers) in the yam value chain. Interestingly, the Yam Improvement Section of CSIR-SARI is developing a number of improved varieties which are high yielding, early maturity, resistant to disease, and having good sensory qualities. This research was conducted to assess the storage stability and nutritional composition of seven yam accessions, which are being developed by CSIR-SARI and proposed for release to the National Variety Release Committee of the Ministry of Food and Agriculture. The specific objective was to assess the shelf-life and nutritional composition of seven advance yam accessions in northern Ghana. The experiment was conducted at CSIR-SARI's storage room located at Nyanpkala (9˚42 ' N latitude and 0˚92 ' W longitude and 184 m altitude) in the Tolon District of Northern Ghana. Seven accessions of yam (SDr 1403074, SDr1403004, SDr1403017, SDr1403005, SDr1403003, SDr1403031, and TDr95/19177) were studied. Shelf-life data collected include decay incidence, physiological weight loss and sprouting. The compositional data collected include; moisture, crude ash, crude fibre, crude protein, and

total carbohydrates. The experimental set-up was a single factor experiment in a completely randomized design with three replications. One-way analysis of variance (ANOVA) procedure was used for testing the effect of genotype using the Genstat (14th Edition) software. Fischer Least of Significant Difference (LSD) method was used to segregate treatments which were significantly different at 5% level of probability. The genotype varied significantly for tuber circumference ($P< 0.01$), tuber length ($p<0.001$) but no significant difference was observed for physiological weight loss ($P<0.05$). Tuber circumference ranged from 30.2cm - 21.7cm. The genotypes with larger circumference were SDr1403003 (30.2cm) and SDr1403074 (29cm). Tuber length ranged from 27cm - 36.9 cm. However, SDr1403031 was the longest (36.9cm) whiles TDR 95/19177 was the shortest (27cm). There was no significant difference in decay of the genotypes although SDr 1403074, SDr 1403005, and SDr 1403031 had no rot all. Variety and dormancy influenced the genotypes to be stored for 16 weeks with minimal deterioration however, these new genotypes from the Yam Improvement Section of CSIR-SARI are recommended to facilitates the choice of varieties with good storage stability to combat the pertinent short duration storage problem in Northern Ghana and Ghana as large.

ACKNOWLEDGEMENT

I am forever grateful to God Almighty for His gift of knowledge, favour, guidance and strength throughout the course of my study and the successful completion of this work in spite of all the challenges. My profound gratitude goes to my selfless supervisors, Dr. Mohammed Mujitaba Dawuda of University for Development Studies and Dr. Issah Sugri of Savanna Agricultural Research Institute – Council for Scientific and Industrial Institute, for their effective supervision, support, encouragement and patience from the inception of this work to its completion. My profound thanks go to Dr. Chamber for the experimental materials and the financial support as well as the field workers at SARI for their assistance and support during the storage stage of this work. My thanks also goes to the Laboratory Technicians for the nutritional analysis of the tubers. I am also grateful to the staff of the department of Horticulture (UDS) for their support.

My final appreciation goes to my family and friends who supported me throughout the period of my study. May God richly bless all those who have contributed to the successful completion of this work.

DEDICATION

I dedicate this work to my parents Mr. Masaudi Yahaya and Mrs. Sakinatu Masaudi and my children, Waseem, Waris and Walid for their unflinching support throughout my studies.

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CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Yam (*Dioscorea* spp.) is a major tuber crop that serves as a staple to thousands of households particularly in the developing world (Wu *et al*., 2016; Akinbo *et al*., 2016; *Obidiegwu et al*., 2020; Kiba *et al*., 2020; Aighewi et al., 2021). West Africa in particular, is noted for growing the majority (92%) of yam produced worldwide (Aighewi *et al*., 2021). In Ghana, yam is consumed by many households, contributes to food security, and it is also a source of income to many farm families (Amponsah *et al*., 2017). Among the several root tuber crops cultivated in Ghana, yam is ranked second to cassava in terms of production and utilization (MoFA, 2013). Yam is intensively cultivated across many parts of Ghana. Due to high consumption of yam which utilized in diverse forms (e.g., boiled, roasted, pounded into fufu etc.) in northern Ghana, most of the smallholder farmers are attracted to its cultivation (Demuyakor, 2013).

Yam belongs to the *Dioscoreaceae* family consisting of true yams (Sadik, 1988; Obidiegwu *et al*., 2020). There are over 600 yam species worldwide, but few species are found in the tropical regions of West Africa including Ghana (Akinbo *et al*., 2016; Garedew *et al.*, 2017). The major species within tropical Africa include the yellow yam *(Dioscorea cayenensis*), white yam (*Dioscorea rotundata*), water yam (*Dioscorea alata*), trifoliate (*Dioscorea dumetorum*), aerial (*Dioscorea bulbifera*) and *Dioscorea esculenta* (Hahn *et al*., 1987).

Nutritionally, yam is a source of essential nutrients such as carbohydrates, vitamins, lipids, proteins and minerals (Mignouna *et al*., 2008; Fauziah *et al*., 2020). According to Fauziah et al., (2020), yam contributes over 200 dietary calories per individual for more

than 300 million people within tropical Africa on daily basis. The therapeutic potentials of yam as a bioactive compound has been documented (Guaadaoui *et al*., 2014). Several compounds such as phenols, tannins, flavonoids, saponins, and alkaloids are found in different varieties (Akinbo *et al*., 2016). Other studies have outlined the pharmacological contributions of yam peptides and proteins to include immunomodulatory, antioxidant, estrogenic, carbonic anhydrase and trypsin inhibiting, chitinase, angiotensin I-converting enzyme inhibiting, anti-dust mite, lectin, anti-insect and anti-proliferative (Zhang *et al*., 2019). Other therapeutic potentials of yam include clinical use for treating diseases such as inflammatory and cardiovascular diseases, menopause and aging disorders, osteoporosis and cancers (Obidiegwu *et al.*, 2020). Some species have been used to cure skin diseases and in birth control mechanisms (Kumar *et al*., 2018). Many cosmetic products are produced from the different varieties of yam (*D. hispida*) (Nashriyah *et al*., 2012).

Production of yam in the tropics is seasonal and storage is the main vehicle in extending its shelf-life into the lean-season. However, in storage, the shelf-life is hindered by several factors including; the yam variety, dormancy, temperature, moisture content, pests (insects, parasites and rodents) (Mahmud and Idris, 2017). Researchers reported that fresh yam are highly perishable and vulnerable to deterioration in storage (Adebowale *et al*., 2018; Afoakwa & Sefa-Dedeh, 2001; Polycarp *et al*., 2012). High moisture content coupled with injuries during harvesting makes the tubers vulnerable to microbial attacks in storage (Ovono *et al*., 2010). Just prior to the breakage of dormancy during storage of the yam tuber, sprouts are formed beneath the periderm (Ovono et al., 2010) which convert the stored carbohydrates into energy for growth thereby accelerating losses and reducing the shelf life and quality of the yam. Some yam varieties in Ghana such as '*dente*', '*pona'* and '*labreko*' do not store for more than six months as results of microbial

attacks (Nyadanu *et al*., 2014). In storage, yam tubers lose some nutritional qualities due to sprouting, which is a physiological process that results in the loss of some nutrients as well as some changes to their internal composition (Adebowale *et al*., 2018). Robertson and Lupien, (2008) reported that under normal storage conditions, weight loss can range from 10 to 25 % within three months. Osunde (2008) identified sprouting as the leading cause of postharvest failures in yams, including weight loss, insect attack, and microbiological attack. Respiration and transpiration, which are enhanced by sprouting, have a significant impact on weight reduction (Kader, 2004). Metabolic losses in yams may account for one-third of overall weight losses in healthy tubers during storage.

1.2 Problem Statement

In spite of the massive contribution of yam to the socio-economic development of Ghana, the producers have over the years struggled with storage issues which often result in postharvest losses (Nyadanu *et al*., 2014; Amponsah *et al*., 2017). Yam is cultivated seasonally but consumed all year round, suggesting that proper storage methods are necessary to promote all-year-round availability. Yam farmers go through a plethora of challenges including the use of indigenous storage techniques, which is not able to preserve tuber quality during prolong period of storage (Amusa *et al*., 2003; Raphael *et al*., 2015; Ray, 2015; Gwa and Ekefan, 2017).

In northern Ghana, farmers depend on indigenous methods of storage, which is associated with varying degrees of postharvest losses (Nyadanu *et al*., 2014). As a result, postharvest losses have been highlighted as the number one problem facing the yam value chain actors (Tenadu, 2016; Holcroft, 2018). Studies show that between 20 – 80 % of yam produced annually goes waste in Ghana (Addae, 2013). The problem of postharvest losses of yam spanned across all the yam producing countries and requires significant attention by all the value chain actors.

Several factors such as primary and secondary factors are responsible for the postharvest losses of yam. The primary causes are type of variety, production practices, soil nutrition, pests and diseases, harvest season, harvest practices, handling practices, storage methods and others (Holcroft, 2018; Leunufna, 2020). This notwithstanding, tuber and root crops are regarded high in the provision of carbohydrates (Maalekuu *et al*., 2014; Osunde and Orhevba, 2009) and the principal energy source in the daily diet of many Ghanaians in the form of locally culinary such as 'Fufu' or 'Ampesi'. It is reported by Maalekuu et al., (2014) that, yam provides 200 calories daily per person to approximately 150 million people in West African alone. Aside, being energy provider, it is relatively rich in protein and minerals including; phosphorus, iron, calcium and vitamins B and C (Maalekuu *et al*., 2014). In the light of this crucial energy provider and other vital supplements many indigenes have tried to ground it into flour for preservation into the lean-season with its nutritional characteristics being in-tacked which is usually used to prepare 'amala' in Nigeria (Nwafor *et al*., 2021).

1.3 Justification for the study

This study is paramount since the threshold of losses are far below current estimate of postharvest losses of yam in Ghana. Several primary and secondary factors are responsible for the postharvest losses of yam. Information generated from this study will be pertinent to developing integrated management practices towards preventing postharvest losses in Ghana. This study will help deepen understanding and facilitate the choice of varieties with good storage stability. In general, prolong storage helps to increase food availability and reduces price variability, which can contribute to the attainment of the United Nations Sustainable Development Goals (e.g. SDG 1, 2 &3) in Ghana. It is therefore imperative for more scientific studies to be conducted on improved postharvest handling and storage methods to reduce current postharvest losses in Ghana.

The Yam Improvement Section of CSIR-SARI is developing a number of improves genotypes which possess high yielding, early maturity, disease resistance and good sensory qualities. This component of the research is to assess the storage stability and nutritional composition of seven yam accessions. These accessions are being developed by CSIR-SARI and proposed for release to the National Variety Release Committee of the Ministry of Food and Agriculture.

1.4 Main Objective

To assess the shelf-life and nutritional composition of seven advanced yam accessions in northern Ghana.

1.4.1 Specific objectives

(i) To determine the nutritional composition of the accessions during prolong storage

(ii) To determine the shelf- life potential of seven accessions under farmer storage conditions.

CHAPTER TWO

LITERATURE REVIEW

2.1 Taxonomy of yam

Yam belongs to the monocotyledonous angiosperm in the Liliflorae order, *Dioscoreaceae* family, and the genus of *Dioscorea* (Wumbei *et al*., 2019). It is considered to be one of the most primitive angiosperms, with over 600 species (Saroya, 2017). Otegbayo, (2018) reported six (6) *Dioscorea* spp. that are thought to be cultivated for food in the tropics out of the 600 species mentioned. The 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*), trifoliate or bitter yam (*Dioscorea dumetorum*) are the edible species been cultivated in the tropics (Demuyakor *et al*., 2013). Linnaeus was the first to described the genus *Dioscorea* in three species in 1753, although it was later divided into five botanical sections by Knuth in 1924 with Enantiophyllum been the largest that include Guinea yam and *Dioscorea cayenensis* which are the most important species in West African in terms of edibility.

2.2 Origin and Distribution of yam

Yams have a long-time history in Africa, Asia, South America, the Caribbean, and the South Pacific islands, with reports indicating that *Dioscorea rotundata* was domesticated in West Africa around 5000 BC. Yams can be traced back to three different regions: West Africa, Southeast Asia, and tropical America. *Dioscorea* species from various parts of the world have been discovered. Many people grow yams in tropical regions all over the world along the 'yam belt,' which is an imaginary line that runs roughly north and south of the equator. The largest and most important yam is considered to have begun in the tropics of South East Asia, South America, and Africa (Arnau *et al*., 2010). White yams (*D. rotundata* Poir.) and yellow yams (*D. cayenensis* Lamk.) are two economically

important species that originated in West Africa and are among the few truly West African domesticated plants (Orkwor, 1998). Yams native to southern Asia, such as the water yam (*D. alata)* and the sweet yam (*D. esculenta* (Lour.)), were introduced to West Africa in recent centuries (Nweke, 1996). Coursey, (1967) reported that wild yams species grow in Nigeria and their tubers are harvested and eaten when food is scarce. The West African yam belt stretches between latitudes 25˚N and 15˚S and includes Cameroon, Nigeria, Benin, Togo, Ghana and Cote d'Ivoire (FAO 2000).

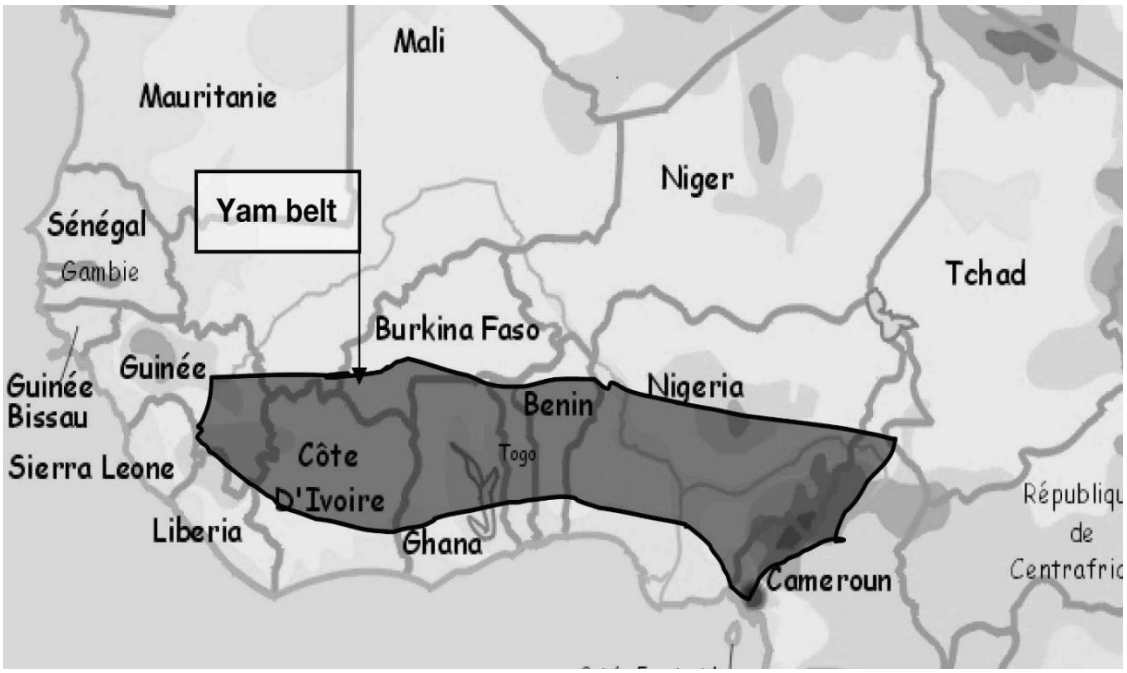

Figure 1: Yam cultivation belt of West Africa

Source: Cirad, (11 December, 2009).

2.3 Importance of yam

Yam is one of the most common food crops in tropical countries and especially in Africa. Africa is the largest producer from extending from east to west through central Africa, it is however the West African region which is with about 96 % of total production area of yam cultivation (Degla and Sourokou, 2020). Regionally and globally, the largest producer remains Nigeria, followed by Ghana, Ivory Coast, and Benin (Degla and

Sourokou, 2020; Mesa-Valle *et al*., 2020). They are also the largest consumers with almost the same culinary practices whose best-known expression in the sub-region is pounded yam. Yam is therefore an important food crop in the sustainable fight against food security and household poverty in these countries (Degla and Sourokou, 2020). The edible yam has been classified as one of the important perishable staple diets. Among the tropical root crops, yams provide food for about 400 million people (Ovono *et al*., 2010). Food prepared from yam is always preferred at social gatherings. Yams are excellent sources of carbohydrate energy and they provide 200 dietary calories per day to over 60 million people (Osei-Sarpong, 2009). Moreover, yams are good sources of medicinally important metabolites like diosgenin (De and De, 2005), dioscorin (Hou *et al*., 1999) and antioxidants (Isamah *et al*., 2000). Some yams are also used as medicines in oriental countries to prevent diabetes (Grindley *et al*., 2002). Thus, yams are considered to be useful to human health and they also have nutritional superiority when compared with other tropical root crops. They are also relatively nutritious, providing some vitamins (including vitamin C), minerals and dietary protein (Osei-Sarpong, 2009). In Ghana, yam is produced nationwide, it is however in the northern part of Ghana that it is most widespread and remains a strategic crop in food security and income generation for the populations. The importance of the yam with its two main species, *Dioscorea rotundata* and *Dioscorea alata* in the diet of these populations leads most households to focus their farm around the production of this crop.

2.4 Production of yam in Ghana

Yam is a main tuber crop grown all around the country. Despite being the world's third largest producer, after Nigeria and Cote d'Ivoire, Ghana is the major exporter of yam (Ofosu, 2012). Between 1997 and 2007, per capita yam consumption climbed by 13% (Anaadumba, 2019). Yam is the third most important source of energy in Ghanaian

cuisine, accounting for 20% of total calorie intake (Anaadumba, 2019). Yam accounts for roughly 16% of the country's agricultural gross domestic product (GDP). Furthermore, yam cultivation takes up 6.3 percent of Ghana's arable area (Anaadumba, 2019).

The majority of yam production in Ghana is done by smallholder farmers with basic hand equipment. As a result, yam farming is labour-intensive, particularly in terms of land preparation. Additionally, the majority of yams grown in Ghana are grown using a shifting cultivation strategy, in which farmers cultivate a piece of land until it is no longer fertile, then move to another plot, leaving the previous one fallow. Yam farming is also seasonal, with the primary harvest season falling between August and December, and a low crop season falling between May and July. Harvest season begins much sooner in the Volta Region than it does in the Northern Region. Yam production accounted for around 24% of total roots and tubers production in the country between 2005 and 2010 (MoFA, 2011). The distribution of yam output across the country is heavily influenced by weather patterns. Yams require high-fertility soils and rainfall for five of the eight months of growth in the field (Eze and Orkwo, 2010). (Sagoe, 2006) indicated that yams do best in regions where yearly rainfall is evenly spread throughout six to seven months of the growth season, ranging from 1000 to 1500 mm. Yam is grown in Ghana in a variety of types. Pona (white yam), Dente, Asana, and Serwa are among them. Ghana's Crop Research Institute (CRI) has released new high yield cultivars, such as the Mankrong and Kukrupa, in recent years. White yam/Pona, on the other hand, continues to be the most popular variety in both local and international markets (Fenwick *et al*., 2005).

2.5 Nutritional composition of yam

Yam is high in carbohydrate, energy, vitamins (particularly vitamin C), minerals, and protein. Okwu and Ndu, (2006) reported high level of ascorbic acid (Vitamin C) in yams grown in Ghana. Many people's diets include yam as a significant source of calories and

a variety of other nutrients. It was even said that yam has far more protein than is often recognized (Osunde and Orhevba, 2009). White yam's crude protein concentration was determined to be between 6.40 and 9.64 g/100g (Lape and Trèche, 1994). This is why many consider white yam to be a good source of nutrients. In terms of nutrition, yam is far more significant than cassava, which is extensively farmed across Ghana. Most yam cultivars have between 6.5 and 11 milligrams of vitamin C per 100g of tuber, however others have as little as 4.5 mg and as much as 21.5 mg/100g. Vitamin C loss in yam tubers during the first four months of storage was very low in undamaged tubers; however, vitamin C loss was substantial in tubers that were injured or bruised prior to storage. The amount of yam consumed by West African families is sufficient to meet each consumer's vitamin C needs. Protein values of 3.2–13.9 % have been discovered in some yam tuber varieties. Phosphorus and vitamins like thiamine, riboflavin, niacin, and ascorbic acid have been found in some edible yams. The chemical makeup of yam is characterized by a high moisture and dry matter content. Carbohydrate, vitamins, protein, and minerals make up the majority of the dry matter. The nutrient content varies depending on the species and cooking method. Yams may also include polyphenolic chemicals (such as tannins), alkaloids, and steroid derivatives in trace amounts. The main dry matter component of the yam tuber is carbohydrate, which can be classified as starch, non-starch, polysaccharides, and sugar. Starch is commonly converted to sugars in yam tubers, most likely as a result of stressors encountered during growth and storage. Variety, location, and cultural treatment all have an impact on sugar content. Sucrose and glucose make up the majority of the free sugars, with the former dominating. The stated protein content of yam tubers varies greatly between species and cultivars, and is dependent on a variety of factors such as cultural techniques, climate and edaphic parameters in which it was cultivated, harvest ripeness, and storage period. Some cultivars have a high protein content, with *D. alata* tubers having the greatest protein concentration among edible

yams. Despite having a lower protein content than most cereals, yam can provide more protein per acre per year than maize, rice, sorghum, and soybean (Osunde, 2008). Cooked yam's utility as a protein source, on the other hand, is restricted by its mass, which is due to its high-water content.

Table 1: Nutrient composition of yam

Nutrient	Amount	Unit
Water	69.6g	g
Energy	118	Kcal
Protein	1.53	g
Total lip (fat)	0.17	G
Carbohydrates, by difference	27.9	G
Ash	0.82	G
Fibre Total dietary	4.1	G
Sugar	0.5	G
Calcium (ca)	17	Mg
Iron (Fe)	0.54	Mg
Magnesium (mg)	21	Mg
Phosphorus (P)	55	Mg
Potassium (K)	816	Mg
Sodium (Na)	9	Mg
Zinc (Zn)	0.24	Mg
Copper (Cu)	0.178	Mg
Manganese (Mn)	0.397	Mg
Vitamin C	17.1	Mg

USDA Nutrient Database, 2019.

2.6 Types and Varieties of Yam

Yam (*Dioscorea* spp. L.) is a tuber crop that is propagated vegetative method. In the family Dioscoreaceae, it is a polyploidy that relates to annual or perennial herbaceous climbing or trailing crop plants that are monocotyledonous. There are many uses for the crop's underground and/or aerial tubers, bulbils and rhizomes, including a source of food, feed and drugs or medicines.

Six (6) of the over 600 *Dioscorea* species are cultivated for food in the tropics (Demuyakor et al., 2013). There are six (6) edible yam species: *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 dumet* (Degras, 1993). *D. rotundata* and *D. alata* cultivars account for the majority of yams grown in Ghana. Although yam is grown throughout Ghana, the Northern and Brong-Ahafo regions produce the majority of the country's supply.

2.6.1 *D. alata*

There are many names given to *D. alata* depending on the region of cultivation but the common name in English is ‘purple yam’. The tuber’s flesh is violet-purple to bright lavender in colour hence the common name ‘purple yam’. The species originated from the Asian tropics (Zhang *et al*., 2018). It is one of the major species of yam that was domesticated and cultivated independently in Southeast Asia and New Guinea due to its importance as staple food crop in the Austronesian cultures. *D. alata* is a tropical plant that thrives in hot, humid conditions. It is rarely found where cool temperatures or dry conditions predominate during the growing season. The primary starchy food in every one area is *D. alata*; however, it is almost always used as one of farinaceous crops (other yams, cassava, sweet potatoes, and aroids) that are used interchangeably to some extent. When introduced to the Tropics, where growing conditions are ideal, It developed into

new varieties within a short time. In West Africa, where it has gained acceptance, it now competes with two important native species, *D. rotundata* Poir. and *D. cayenensis* Lam.

2.6.2 *D. rotundata* and *D. cayenensis*

Dioscorea rotundata and *Dioscorea cayenensis* are the most popular and economically important yams in West and Central Africa, as reported by (Mignouna and Dansi, 2003), while *Dioscorea alata* is the most widely distributed species globally**.** Reports suggest that *D. rotundata* and *D. cayenensis* were domesticated in the forest zones of West Africa especially along the belts of Ivory Coast to Cameroon. Although the actual mechanism of domestication is unknown, it is widely accepted that the highly developed West African tribal civilizations arose in connection with yam cultivation. Even though the two species are sisters with respect to zone of domestication, they are easily distinguished as they appear to have hybridized frequently and there are a variety of intermediate forms that make accurate classification difficult. The two species *D. rotundata* and *D. cayenensis* are found in the Enantiophyllum section, which is the most significant section of the genus. Only the Old World is aware of this section. This section's tubers are usually upright, and the foliage is plain. The section also includes the Asian species *D, alata* and *D, opposita* Thunb., as well as the important African species *D. abyssinica Hockst., D. colocasiifolia* Pax, *D. lecardi* de Wild., *D, liebrechtsiana, D. mangenotiana Miège*, and *D. praehensilis* Benth., some of which are used for food in special circumstances. Burkill has provided descriptions of the approximately 50 Asian species as well as the approximately 100 African species (Arackal, 2015).

2.6.3 *D. dumetorum*

Dioscorea dumetorum has a bitter flavour, as its popular English name (Bitter yam) suggests, and grows wild across Africa, primarily in West Africa. It has three-branched compound leaves that distinguish it from other yams with single heart-shaped leaves, as

well as a short stem that twines anticlockwise. Hairs and spikes are seen on the stem. The tuber is a gritty, juicy tuber that grows in bunches. Tubers of *D. dumetorum*, as well as tubers of other wild plants, are commonly used in times of food scarcity. Some researchers have reported that *D. dumetorum* in fresh state is poisonous as well as containing some alkaloids including dihydrodioscorine, dioscoretine (Adeniran and Sonibare, 2017) etc. However, *D. dumetorum* is reported to have health benefits for treating diabetes in Nigeria. Nimenibo–Uadia, (2003) found the aqueous extract of *D. dumetorum* to be effective in lowering blood glucose, lipids, and ketones in diabetic animals. It is also nutritionally better than frequently consumed yams, containing high protein and mineral content. It possesses smaller, more easily digestible starch grains than other yam species. However, the tuber of the trifoliate yam includes certain anti-nutrients, which might cause a minor bitterness (Kelechi *et al*., 2017). Furthermore, a few days after harvest, this yam species hardens, resulting in a decrease in moisture and starch content and an enhancement in sugar and structural polysaccharides (Afoakwa and Sefa-Dedeh, 2001).

2.7 Postharvest losses in yam

In developing countries, tuber crop postharvest losses are more severe than in developed countries. Yam is one of the tuber crops that is easily perished after harvest due its high metabolic activities in storage. In 2008, Ghana's Ministry of Food and Agriculture (MoFA) conducted a baseline assessment on harvest and postharvest (HPH) losses among major crops across some regions, and the overall conclusion was that HPH losses were ridiculously high. Postharvest losses are caused by a lack of appropriate processing facilities, postharvest storage techniques, and management practices. Asiedu and Sartie, (2010) categories the losses of yam into quantitative and qualitative losses. Weight loss, primarily due to moisture loss through transpiration is the main quantitative type of loss.

Dry matter losses, and nutrient loss due to sprouting and respiration are examples of qualitative losses. Postharvest losses of yam in the developing countries is hasten by poor storage facilities, poor handling strategies by the farmers and poor road network from production centres to market centres. The root and tuber crop farmers in the tropics particularly West Africa do not get fair pricing for their produce and some of them are forced to store these yam tubers to a lean season, where they can bargain fair prices. But the high postharvest losses cause significant economic challenge Odigboh, (2004) estimated that yam post-harvest losses in Nigeria are greater than 25% per year. In addition, yam transit losses of 15-40% occur due to inefficient storage and transportation facilities (Opara, 2003). This is confirmed by Robertson and Lupien, (2008) that weight loss after three months of storage ranges between 10-20 percent and 50 percent after six months respectively. Over the years, storing fresh yam tubers has proven to be a major challenge. Kader, (2004) and Imeh *et al.*, (2012) suggested that physiological and pathological factors contribute to yam losses in storage.

2.8 Major causes of yam losses in Ghana

Yam tubers are difficult to store and are prone to postharvest losses when fresh (Afoakwa and Sefa-Dedeh, 2001). According to research into the causes of storage losses, factors such as respiration, sprouting, rot-causing organisms, rodents, and moisture loss are all to blame (Nwaigwe *et al*., 2015). Significant pre-harvest factors leading to losses are cultural practices, field pest attacks, disease organism infections, environmental, and genetic factors are among these factors. Physical damage, rodent attack, fungal and bacterial diseases, and physiological processes such as sprouting, dehydration, and respiration all contribute to yam post-harvest losses. Another classification of the causes of losses are mechanical damage, physiological changes and infections due decaying organisms (Opara, 2003). Post-harvest yam losses result in price reductions; which is

economic losses for farmers and others involved in the yam value chain (Wenham, 1995; Naziri *et al*., 2014).

2.8.1 Diseases and Pests of yam

Postharvest diseases associated to yam losses in Ghana were described by (Anaadumba, 2019). According to the report, 30 % of tubers harvested have nematodes, 20 % have termites, 13% percent have internal browning, 50-90% percent have postharvest tissue damage due to tuber stacking, 38 percent have rot development, and 3 percent have been damaged due to prolonged exposure of tubers to intense sunlight in the market place. Yams are cultivated in places that receive a lot of rain and have a four-month rainy season. Because yams are grown in the field for five to ten months, their shoots, roots, and tubers can be attacked by a variety of diseases. Insect infestations can cause significant productivity losses in yam storage. In surveys conducted in Cote d'Ivoire in 1981, 1983, and 1984, it was discovered that throughout the course of four months of storage, 63 %t of stored tubers were infested by moths, with weight losses of 25 percent ascribed to the insects (Abewoy, 2021). Korada et al., (2010) reported that, the feeding damage by *Heteroligus meles*, *P. caniculus*, and *Aspidiella hartii* allows for the development of fungal infections in tubers. In Nigeria's Asaba and Lokoja state, *H. meles* and *A. hartii* is a major headache to yam farmers as they caused significant damage to seed yams (Aighewi *et al.*, 2002).

Pests and rots were found in the seed yams of between 47 and 90 percent of growers in those areas. In Nigeria, a Yam Moth, *Dasyses rugosella* Stainton (Lepidoptera: Tineidae), was observed by Ashamo and Odeyemi, (2004). In the savannah area, Korada *et al*., (2010) investigated the infestation of stored yams by *Euzopherodes vapidella* Mann larvae for two *Dioscorea* species, *D. alata* and *D. cayenensis*. Mealy bugs produce a white powder on the surface of yam tubers and cause necrosis on sprouts, prohibiting the usage

of seed yam tubers. The bigger yam beetle is notorious for wreaking havoc on yams, especially in West Africa. During their feeding trip from swampy areas, adult yam tuber beetles attack tubers by boring holes and tunnels into the tubers (Vowotor *et al.*, 2013). Not only do the holes and tunnels damage the quality of the yam tubers, but they also affect their market value. Because of the favourable temperatures and humidity in storage rooms, *Aspidiella hartii* (Pillai and Rajamma, 1997; Mignouna *et al*., 2001), *Heteroligus meles*, and *H. appius* (Tobih *et al*., 2007) continue to be serious insect pests of yam tubers. *H. meles* has been identified as the most common cause of yam tuber rots (Korada *et al*., 2010). *Pseudophloesporella dioscoreae* thrives on newly emerging sprouts in storage facilities with insufficient ventilation (Quin, 1985). The primary pests of Lesser Yam (*D. esculenta*) in storage, according to research at the Central Tuber Crops Research Institute (CTCRI) in Trivandrum, India, were *Aspidiella hartii* and *Araecerus laevigatus* (Pillai and Rajamma, 1997). Another notable pest is Coffee Bean Weevil, *A. fasciculatus*, which destroys tubers of Greater Yam *D. alata*, in addition to these two insects (Devasahayam and Koya, 2016).

2.8.2 Pathogens causing rots

Bacteria, fungus, and nematodes are the causes of diseases that harm tubers and occur during harvest, storage, and shortly after emergence. Three harmful bacteria have been linked to storage rots after harvest (Ogunleye and Ayansola, 2014). The development of disease is aided by high humidity and colder temperatures (Legg *et al.*, 2015). The pathogens *Colletotrichum gloeosporioides*, *Botryodiplodia theobromae*, Aspergillus spp., *Penicillium* spp., *Sclerotium rolfsii*, *Curvularia verruculosa*, *Rhizoctonia solani*, and *Fusarium moniliforme* are typically associated with storage rots in yam tubers (Uma, 2009). Several of these fungi are frequently isolated from foliar lesions (Green, 1994; Amusa *et al.*, 2003). It's unclear what role these organisms have in the infection process.

In the field, unbruised yam tubers with undamaged periderm are rarely affected by fungi. Accidental cutting and bruising of tubers during weeding, harvesting, and transportation to stores increase fungus invasion into tubers. A total of 13 fungus have been linked to yam tuber pre-harvest issues (Ogunleye and Ayansola, 2014). Most fungi penetrate yam tuber tissues after harvest and produce rots. There have been reports of 30 distinct fungi being linked to storage rots (Suleiman and Ejembi, 2012). The most common rot-causing fungus found in yam tubers is *Penicillium oxalicum* (Nwawuisi *et al*., 2012). In Nigeria, the fungus was responsible for 57 to 77 percent of all yam tuber rots, while in the West Indies, it was responsible for 80 percent of all rots (Okigbo and Ezebo, 2017).

Despite the fact that both yam nematode and root knot nematode are linked to yam tuber storage rots, the former is the predominant pest of yam tubers in storage (Coyne *et al*., 2018). The yam nematode that infects the peridermal and sub-peridermal layers of tubers increases its population during storage and can penetrate deeper into the tubers, producing both dry and wet rot. This results in significant tuber storage losses. The yam nematode damage predispose tubers to pathogenic organisms, notably fungus and bacteria, to enter and cause wet rot during storage (Coyne *et al.*, 2006). In the later stages of wet rot, the yam nematode is not directly involved (Coyne *et al*., 2006). In some places of Nigeria, the yam nematode can cause loss es up 80-100 % of stored tubers (Akinbo, 2019). Virus infections in cultivated and wild yams, particularly *D. rotundata*, *D. cayenensis*, and *D. praehensilis* Benth, have been linked to a variety of viruses from several virus genera. *Potyvirus*, *Badnavirus*, *Cucumovirus*, *Potexvirus*, *Comovirus*, and *Carlavirus* are among the several virus genera (Umber *et al*., 2020; Kenyon *et al*., 2003).

Yam mosaic virus (YMV), Yam mild mosaic virus (YMMV), Cucumber mosaic virus (CMV), *Dioscorea* mottle virus (DMV), *Dioscorea alata* Badnavirus (DaBV), and *Dioscorea alata* virus (DAV) generally known as Yam virus 1 (YV1) are the six main

yam viruses known to inflict substantial economic harm to yam in Africa (Kenyon *et al*., 2003).

2.9 Yam storage

In Africa, particularly West Africa, yam is burdened with a lot of losses both in the field and in storage. Losses are common in yam "stores", and much of the harvested produce is squandered through diseases, nematodes, insects, and sprouting. Yam storage is complicated by a variety of issues, many of which are beyond the control of the average farmer. Postharvest losses are a major concern, with various sources estimating that 20-80 percent of produced yams are lost after harvest. Because yam is an annual crop, harvested tubers must be preserved for six to eight months until new yams are collected. Dormancy, which occurs shortly after physiological maturity, has a significant impact on the ability to keep fresh yam tubers. The tuber's metabolic function is reduced to a bare minimum during dormancy. Natural dormancy can last anywhere from four to eighteen weeks depending on the yam variety (Osunde and Orhevba, 2009). A significant quantity of yam is lost during the storage period. Afoakwa and Sefa-Dedeh, (2001) and Serge and Trèche and Agbor-Egbe, (1996) reported changes in carbohydrates, sugars, and protein were observed during long-term preservation of yam tubers. After 72 hours of storage, yam tuber *(D. dumetorum*) stored in ambient and cold room settings found a quick decline in moisture and starch contents, as well as an increase in total alcohol-soluble sugars and reducing sugars (Afoakwa and Sefa-Dedeh, 2001). Condensation, respiration, and germination are examples of endogenous, or physiological, losses. Exogenous factors such as insects, pests, nematodes, rodents, rot bacteria, and fungi on the stored product cause other losses (Osunde, 2008).

2.9.1 Physiological causes of losses of yam in storage

2.9.1.1 Transpiration

In fresh food like tubers, one of the most important physiological processes is transpiration. Once the produce has been separated from the plant's roots, it is totally reliant on its own water supply to survive (Mahajan *et al.*, 2008). Various parameters such as surface-to-volume ratio, surface injuries, morphological and anatomical traits, as well as maturity stage, influence the transpiration rate (TR) of produce during postharvest handling and storage (Xanthopoulos *et al.*, 2017) and temperature, relative humidity, air velocity, and atmospheric pressure are examples of external variables (Chourasia *et al*., 2005).

2.9.1.2 Sprouting and Dormancy

Afoakwa and Sefa-Dedeh, (2001) indicated that sprouting of tubers in storage renders them unsatisfactory for eating as carbohydrates, sugar and other nutrients are deteriorated. The time of dormancy in yam is described as a period of rest as reported by (Craufurd *et al.*, 2001). At the stage of dormancy, all endogenous metabolic processes are reduced to the barest minimum. Sprouting which marks the end of dormancy lead to depletion of nutrient research in tubers. Therefore, all new sprouts should be pruned quickly to reduce the rate of nutrient depletion.

2.9.1.3. Respiration

Yam tubers are living organs even after harvest. The process of respiration convert starch into water, carbon dioxide, and heat energy (Mwinibalonno, 2015). The dry matter of the tuber is decreased during the starch transformation. The respiration rate of yam is generally high at or immediately after harvest, then gradually decreases during storage. It is stated that once sprouting begins, the rate increases again (Filli *et al*., 2019). The

production of black heart, a condition induced by central cell asphyxiation, can be triggered by increasing high temperatures (Kwesi, 2013).

2.10 Storage conditions of yam tubers

The most critical three requirements for optimal yam storage are low temperature, aeration, and frequent tuber inspection (More *et al*., 2019). Aeration keeps moisture out of the tubers and aids in the cooling of the barn after respiration. To avoid losses due to tuber respiration, sprouting, and rotting, the temperature must be kept at the optimal level. However, the best storage temperature is between 12 and 15 degrees Celsius, beyond which physiological damage, such as chilling injury, can occur. It's critical to inspect the tubers on a regular basis for sprouts and rotting tubers, as well as rat and other pest activity (FAO, 2003). Low temperatures stifle the produce's normal metabolic activities, delaying ripening, senescence, sprouting, and other processes. However, necessary measures must be taken to minimize chilling damage, especially when using products with a high moisture content (Rees *et al*., 2012). To encourage suberization of damaged tissues and hence avoid infections during storage, the tubers must be treated to a curing period prior to cool storage (Rees *et al*., 2012). Few researchers have looked into the impact of lower temperatures on the quality of *Dioscorea* spp. in yam storage. *Dioscorea rotundata* were preserved at 1.1° C (34° F) for 10 days in experiments conducted in Puerto Rico in 1937 (De Graaf, 2008). The tubers were completely depleted physiologically at this point. Similar observations were made by After 3 to 4 weeks, tubers kept at low temperatures lost a lot of weight and went through a complete physiological deterioration. Cured tubers are considered to be best stored at a temperature of 16 degrees Celsius and a humidity of 70%. Yam may be stored for 3 to 4 months at temperatures above 16 °C. Tubers that have been treated should be kept at a low humidity level. Chilling damage can occur at temperatures below 12 °C.

2.11 Methods of yam storage in Ghana

To get a decent market price, Ghanaian farmers prefer to preserve harvested yam tubers for a time before selling them. However, they often experience large storage losses, which has resulted in a rise in the price of yam tubers, forcing yam enthusiasts to turn to cassava as an alternative (Tetteh and Saakwa, 1991). Some yam species store better than others and Farmers are typically aware of this problem and they usually consumed cultivars with poor storage qualities or sold as soon as possible after harvest. Wilson and Hamilton, (1987) reported that, the best storing cultivars have:

i. good nematode resistance
ii. a protracted period of inactivity
iii. ability for healing when cut or scraped
iv. compact shapes which limit the chance of tubers being bruised accidently during harvest.

There are several traditional methods yam farmers have used in storing yam over the years in the tropics. Yam storage structures vary in design and size based on the farmer's abilities, location, and cultural practices. Wood, ropes, palm fronds, guinea corn stalks, and mud are commonly used as construction materials (Umogbai and Satimehin, 2004).

2.11.1 Storage in traditional yam barn

Traditional yam producers in West Africa use this storage system the most. A yam barn is made up of vertically built wooden posts that are roughly 3 m long and 50 cm apart. Vertical posts are erected by horizontal posts attached to them. For both static reasons and to give natural shade, trees that are still growing are frequently included into the storage system. The Guinea Savannah zone's yam barn is made with crop by-products such as guinea corn stalks, sticks, grass, and yam vines. The yams are piled in various locations throughout the barn (Osunde, 2008). Every year, such barns are built under a

tree shade to protect the tuber from scorching sun and extreme heat. The yam barn is burned down when tubers are collected to make way for new planting season (Osunde, 2008). In a barn, yams have a maximum storage life of six months. During the first three months, losses can range from 10 % to 15 %, and after six months, losses can range from 30 % to 50 % (Ofor *et al*., 2010). Yam barns are ineffective during the wet season because the moist climate encourages tuber decomposition.

2.11.2 Trench silos

A pit is dug and a straw or similar material is used to line the dug trench. Tubers are stacked horizontally up to upper part of the trench. The pit can be built underground or above ground, depending on how much tubers are to be stored. The pit is covered with straws or the material used. Lack of airflow and contact infection of disease pathogens are the challenges of this method. Rodents can also find a safe haven in the pit.

2.11.3 In-situ storage

In this method, the farmer leaves tubers in the mounds after maturity. Tubers are harvested from the mounds depending on the variety and as long as the farmer wants. This particular method has a lot of challenges including; termites, nematodes, rodents attacks on tubers etc. Adeyinka et al., (2011) indicated that, depending on the variety tubers can last four months maximum in the mounds.

2.11.4 Platform storage

Yam tubers are stored on raised platforms in a shed to prevent direct exposure of sun and rains on tubers in the farm. A concrete floor could be raised above the ground in the shed to prevent rodent action. One important factor to be considered in the construction of this storage system is ventilation.

2.11.5 Hanging

Yam tubers are hung under a shade to prolong shelf-life after harvest. The tubers can be hanged up to three months. They are then moved to a protected shed and covered in a layer of dried grasses or straw when the farmer is satisfied with the curing process.

2.11.6 Conical protective roof

This kind of storage is frequently built beneath a shade tree. It comprises of a protective conical roof. The shady tree reduces temperature swings during the day, and the light protective roof allows for enough airflow. Tubers are stacked on top of one another and the roof covered entirely prohibiting routine visual inspection (Ofor *et al*., 2010).

CHAPTER THREE

MATERIAL AND METHODS

3.1 Experimental field

This experiment was conducted at CSIR-SARI storage facility located at Akukayili, Nyankpala (9˚42' N latitude and 0˚92' W longitude and 184 m altitude) in the Tolon District of Northern Region of Ghana. The study area falls within the Guinea Savannah Zone of Ghana with a unimodal rainfall pattern. Relative humidity of the area is about 60-84% in the raining season (June-November), and 40- 55 % during the dry season (November-April) (SARI, 2004). Storage of the yam accessions commenced on January 2021 and ended May 2021.

3.2 Source of yam tubers

Seven accessions of yam (SDr 1403074, SDr1403004, SDr1403017, SDr1403005, SDr1403003, SDr1403031, and TDr95/19177) were studied. The accession, TDr 95/19177, was used as standard susceptible check (control). The selection of tubers was carefully done to exclude mechanically damaged or infested tubers, and only medium size wholesome tubers were stored. The tubers were individually trimmed to remove root debris.

3.3 Method of sampling

The experimental design used was a single factor experiment in a Complete Random Design (CRD). There were seven accessions and three replications and each replicate consisted of 7 tubers totalling 147 treatments. Each replicate was put in plastic crates with holes to improve ventilation. The tubers were labelled from 1 to 7 for identification and data collection. The crates were randomly arranged on laboratory bench without stacking to improve ventilation.

Plate 1: Yams in plastic crates with labels

3.4 Data collection

Data were collected on tuber weight, length, and circumference at interval of 2 weeks.

3.4.1. Weight Loss

The weight loss was recorded using the digital weighing balance (Spark 4) (manufacturer: WANT Balance Instrument Co., Ltd.). Three tubers from each accession were selected and weighed before storage, and subsequently at intervals of 2 weeks up to the end of storage period. Loss of weight over the period of storage was determined using the formular below:

$$Weight\ loss\ (\%) = \frac{Initial\ weight - Final\ weight}{Initial\ weight} \times 100$$

Plate 2: Weighing of yams with the electronic weighing balance

3.4.2 Circumference of tubers

Shrivelling is a major challenge during storage. Reduction in tuber circumference was used to determine the extent of shrivelling. The difference between the initial and final circumference (cm) gives the approximate reduction in tuber size over the period of storage. Three tubers from each accession were selected and measured before storage, and subsequently at intervals of 2 weeks up to the end of storage period. Reduction in circumference over the period of storage was determined using the formulae below:

$$Tuber\ circumference\ loss\ (\%) = \frac{Initial\ girth - Final\ girth}{Initial\ girth} \times 100$$

3.4.3 Tuber length

Tuber length (cm) was determined at intervals of 2 weeks using a tape measure. Three tubers from each accession were selected and measured before storage, and subsequently at intervals of 2 weeks up to the end of storage period.

3.4.4 Sprouting incidence

Sprouting data was collected from 6th week after storage, and subsequently at 2 weeks intervals to the end of the experiment. Tubers showing sprouts were counted, and the sprouts were severed and weighed (g) using the electronic weighing balance.

Plate 3: Sprouting was noticed at 5 weeks after storage. The sprouts were countered, nipped and weighed.

3.4.5 Determination of shelf-life

The shelf-life (days) was assessed up to 6 months after harvest. Shelf-life was defined as the number of days that tubers were wholesome and maintained their marketable quality. Through visual observation of the accessions, tubers without decay symptoms were counted and recorded as healthy tubers. Decaying tubers were excluded from the treatments to avoid contact spread of pathogens to healthy tubers.

Plate 4: Visual observation of the tubers for decay symptoms

3.5 Storage Conditions

3.5.1 Temperature and Relative humidity

The yam barn temperature and relative humidity were determined on daily basis using data logger with inbuilt thermometer and a hygrometer (Brand ETI Thermometers). This

instrument was installed inside to record automatically the ambient temperatures and relative humidity of the barn. These parameters were recorded to determine the variations (minimum, maximum and average) in temperature and relative humidity and their effect on shelf-life. Daily temperatures and relative humidity were calculated on monthly basis (Table 2).

Table 2: Monthly averages of Temperature and Relative humidity for storage period

Month	Minimum Temp. (°C)	Maximum Temp. (°C)	Minimum Relative Humidity	Maximum Relative Humidity
January	27.34	34.98	16.01	34.58
February	26.66	34.81	16.14	35.25
March	27.96	36.33	35.32	66.14
April	26.93	32.40	53.83	74.60
May	26.18	30.87	60.32	77.58
Average	27.01	33.88	36.33	57.63

3.6 Nutritional characteristics

The accessions were analysed for moisture content, crude protein, total carbohydrate, pH and ash.

3.6.1 Moisture content

5 g of yam sample was weighed and placed in a moisture dish. It was dried to constant weight at 105 ℃ in a drying oven. Moisture content was determined using the formula below:

$$Moisture\ content\ (\%) = \frac{Weight\ of\ fresh\ sample - Weight\ of\ dried\ sample}{Weight\ of\ fresh\ sample} \times 100$$

3.6.2 Crude protein (%)

Crude protein was determined by using the Kjeldahl digestion method by weighing 1 g of yam sample into 250 ml long – necked Kjeldahl flask to determine the amount of nitrogen contained in the yam samples. After digestion with H_2SO_4, the colourless solution was distilled and titrated. Crude protein was determined by the formulae below:

NB: Weight of l sample used, considering the dilution and the aliquot taken for distillation

$$= \frac{2g \times 10\ ml}{100ml} = 0.2g$$

Thus, the percentage of Nitrogen in the plant sample is,

$$\%\ N = \frac{14 \times (A - B) \times N \times 100}{1000 \times 0.2}$$

Where:

A = volume of standard HCl used in the sample titration

B = volume of standard HCl used in the blank titration

N = Normality of standard HCl

% Crude Protein (CP) = Total Nitrogen (N_T) x 6.25(Protein factor)

3.6.3 Crude Fat

2 g of dried yam sample was weighed and placed into extraction thimble placed in Soxhlet apparatus and connected to pre-weighed solvent flask. Petroleum ether of about 150 – 200 ml added and then connected to a condenser and extract for 2 – 3 h. Ether was reclaimed in a boiling bath at 105 ℃ for 30 minutes and then cool in a desiccator. Crude fat was determined by the formula;

$$Crude\ protein\ (\%) = \frac{Weight\ of\ fat}{Weight\ of\ sample} \times \frac{100}{1}$$

3.6.4 Crude Fibre

2 g of dried, fat-free yam sample was weighed and placed into digestion flask. 200 ml of sulphuric acid added and allowed to boil for 30 minutes in a condenser and filtered immediately with linen and then washed with boiling water. 200 ml of hot NaOH solution was added to the residue in a new digestion flask and placed in a condenser and boiled for 30 minutes after the initial, 1 minute boiling. It is then filtered through a porous crucible and then washed with boiling water and 15 ml of 95 % alcohol. It is then dried at 105 ℃ until constant weight is obtained. It was then ash at 550°C for 30min, cool, and weighed. Calculation of the weight of fibre by difference was determined using the formula;

$$\boldsymbol{Crude\ fibre\ (\%\ of\ fat-free\ DM) = \frac{(Weight\ crucible + dried\ residue) - (Weight\ crucible + Ashed\ residue)}{Weight\ of\ sample} \times 100}$$

3.6.5 Crude ash

Yam sample of 2 g was weighed into a clean dry, tared porcelain crucible and then arranged in a cool muffle furnace and burnt at a temperature of 500 ℃ for 4 h. The ash was determined by the formula;

$$Ash\ (\%) = \frac{Weight\ of\ ash}{Weight\ of\ sample} \times 100$$

3.7 Data Analysis

The experimental set-up was a single factor experiment in a completely randomized design. One-way analysis of variance (ANOVA) procedure was used for testing the effect of genotype using the Genstat (14^{th} Edition) software. Fischer Least Significant Difference (LSD) method was used to segregate treatments which were significantly different at 5% level of probability. Data on decay incidence was managed using square root transformation.

CHAPTER FOUR

RESULTS

4.1 Storability of seven yam accessions

Tuber circumference and tuber length varied significantly ($p<0.001$) across the yam accessions, but no significant ($P<0.05$) differences was shown for weight loss. Tuber circumference ranged from 30.2-21.7cm. The largest circumference occurred on SDr1403003 (30.2cm) and SDr1403074 (29cm). Tuber length ranged from 27cm - 36.9 cm. The SDr1403031 was the longest (36.9cm) whiles TDR 95/19177 was the shortest (27cm).

Table 3: Characteristics (circumference, tuber length and weight loss) of the seven yam accessions

Accessions	Initial Measurements		
	Circumference(cm)	Length (cm)	Weight loss (%)
SDr1403003	30.2	35.7	3.22
SDr1403004	24.1	31.6	2.51
SDr1403005	22.4	34.2	2.28
SDr1403017	25.1	36.4	2.52
SDr1403031	21.7	36.9	3.59
SDr1403074	29.0	34.2	4.32
TDR 95/19177	22.3	27.0	7.69
Grand mean	25.0	33.7	3.73
Significance level	0.011	0.001	0.06
CV %	23.1	13.2	54.0
LSD(P<0.05)	5.5	4.2	3.52

4.2 Shelf-life of tubers

At 5 months after storage, most of the accessions maintained their marketable quality. Accessions SDr 1403074, SDr 1403005, and SDr 1403031 had 100 % marketable tubers

at the end of storage. Accessions SDr 1403004 and SDr 1403017 had 95 % marketable wholesome tubers. SDr 1403003 and Control (TDr 95/19177) had the least (85 %) marketable tubers, respectively (Table 3).

Table 4**: Number of wholesome tubers at the end of experiment**

Accessions	Number stored	Number of marketable	% Number of marketable tubers
TDr 95/19177	20	17	85
SDr 1403074	20	21	100
SDr 1403004	20	20	95
SDr 1403017	20	20	95
SDr 1403005	20	21	100
SDr 1403003	20	19	90
SDr 1403031	20	20	100

4.3 Decay losses in storage

At seven months after storage, all the accessions maintained marketable quality within acceptable threshold (Table 4). There was no significant differences ($P>0.05$) among the accessions for decay losses. Accessions SDr 1403074, SDr 1403005, and SDr 1403031 had the least decay losses (1.7%) after 7 months of storage. Accession TDr 95/19177 had the highest decay loss of 4.8%.

Table 5: Percentage of Decay losses of yam accessions in storage

Accessions	Decay losses (%)
SDr1403003	3.3 (9.5)
SDr1403004	2.8 (4.8)
SDr1403005	1.7 (0.0)
SDr1403017	2.8 (4.8)
SDr1403031	1.7 (0.0)
SDr1403074	1.7 (0.0)
TDR 95/19177	4.8 (19.1)
Grand Mean	2.7
Significant level	NS
CV (%)	65
LSD (P< 0.05)	NS

4.4 Tuber circumference (cm)

Decrease in circumference indicate the amount of shrivelling during storage. Initial determination of tuber circumference showed significant differences (P<0.01) among the accessions. Tuber circumference ranged from 21.7 cm - 30.2 cm. The largest circumference was in SDr1403003 (30.2cm) followed by SDr1403074 (29cm). Continuous decrease in tuber circumference was exhibited across the genotypes during storage period. The rate of shrivelling ranged from 23- 24.4% at first 10 weeks after storage, and reduced to 20.7-22.4% at 11-16 week after storage. The SDr 1403003 accession had the largest circumference at week two, whilst the Control (TDr 95/19177) had the least (16.8) circumference at week fourteen (Table 6).

Table 6: Circumference of yam accessions during storage

Accession	Circumference (cm)							
	Week0	2 weeks	4weeks	6 weeks	8 weeks	10 weeks	12 weeks	14 weeks
SDr1403003	30.2	29.8(1.3)	29.6(1.9)	29.1(3.6)	28.7(5.0)	28.3(6.3)	27.6(8.6)	27.2 (9.9)
SDr1403004	24.1	23.7(1.7)	22.9(5.0)	21.9(9.1)	21.5(10.8)	20.7(14.1)	19.3(19.9)	18.2(24.5)
SDr1403005	22.4	22.1(1.3)	21.9(2.2)	21.6(3.6)	21.1(5.8)	20.6(8.0)	19.9(11.2)	19.2(14.3)
SDr1403017	25.1	23.5(6.4)	22.9(8.8)	22.7(9.6)	22.1(12.0)	21.6(13.9)	20.9(16.7)	20.0(20.3)
SDr1403031	21.7	21.3(1.8)	21.2(2.3)	21.0(3.2)	20.8(4.1)	20.2(6.9)	19.5(10.1)	18.7(13.8)
SDr1403074	29.0	28.6(1.4)	28.3(2.4)	27.9(3.8)	27.1 (6.6)	26.8 (7.6)	25.9(10.7)	24.6(15.2)
TDR 95/19177	22.3	21.6(3.1)	21.0(5.8)	20.1(9.9)	19.5(12.6)	18.7(16.1)	17.54(21.3)	16.8(24.7)
Grand mean		24.4	24.0	23.5	23.0	22.41	21.5	20.7
Sig. level		0.003	0.002	0.001	<.001	<.001	<.001	<.001
CV (%)		21.8	21.5	21.5	21.6	21.2	21.2	-22.8
LSD (P<0.05)		5.0	4.9	4.8	4.7	4.5	4.3	4.1

*Values in parenthesis represents % reduction in tuber circumference

4.5 Tuber length (cm)

There was significant differences ($P<0.05$) in tuber length among the accessions throughout the storage period. The tuber length ranged from 27.0 cm to 36.9 cm. The longest (36.9 cm) and shortest (27.0 cm) tubers length were in SDr 1403031 and TDr 95/1977 accessions, respectively. There was a general decreasing pattern of the tuber length from week two (33.7) to the last week (24.1) of the storage period (Table 7).

Table 7: Change in tuber length in seven yam accessions stored for 14 weeks

Accession	Length (cm)							
	Week 0	2 weeks	4 weeks	6 weeks	8 weeks	10 weeks	12 weeks	14 weeks
SDr1403003	35.7[ab]	34.4(4.3)	33.4 (6.4)	31.7(11.2)	30.5(14.6)	29.0(18.8)	27.3(23.5)	25.4 (28.9)
SDr1403004	31.6[b]	30.3(5.4)	29.4 (7.0)	27.7(12.3)	26.6(15.8)	25.0(20.9)	24.4(22.8)	23.0 (27.2)
SDr1403005	34.2[ab]	32.6(7.1)	31.8 (7.0)	29.6(13.5)	27.6(19.3)	26.2(23.4)	25.2(26.3)	23.0 (32.7)
SDr1403017	36.4[a]	34.9(6.0)	33.3 (8.5)	31.1(14.6)	29.9(17.9)	28.0(23.1)	26.0(28.6)	24.3 (33.2)
SDr1403031	36.9[a]	35.7(5.5)	34.5 (6.5)	32.6(11.7)	31.0(16.0)	29.5(20.1)	28.3(23.3)	27.1 (26.6)
SDr1403074	34.2[ab]	33.3(3.1)	31.5 (7.9)	30.0(12.3)	28.8(15.8)	28.0(18.1)	27.1(20.8)	26.0 (24.0)
TDR 95/19177	27.0[c]	26.0(4.5)	25.3 (6.3)	24.4 (9.6)	23.8(11.9)	23.0(14.8)	21.7(19.6)	20.2 (25.2)
Grand mean		33.7	32.5	29.6	28.3	27.0	26.0	24.1
Significant level		0.001	0.001	0.001	0.006	0.023	0.039	0.019
CV (%)		13.2	13.1	13.7	14.5	16	16.7	17.4
LSD (P<0.05)		4.2	4.0	3.8	3.9	16	4.1	4.0

4.6 Percentage tuber sprout count

Tuber sprout was observed a month after storage. Early sprouting was observed in TDr95/19177, SDr1403004, SDr 1403017 and SDr 1403003 genotypes. The tubers in all the accessions started sprouting at six weeks after storage. There was no significant difference ($P<0.05$) among the accessions except in week eight of the storage period, which showed significant ($P<0.05$) sprout count. There was increasing of sprouting from the 6th week to the last week of the storage period. However, this pattern was interrupted at week eight which recorded a higher value than the subsequent weeks. TDr 95/19177 (control) had the highest (66.7) sprout count at week sixteen followed by SDr 1403003 (61.9) and SDr 1403017 (61.9) at week sixteen and week fourteen, respectively. However, there was minimal sprouting in SDr 1403005 in weeks 6 to 8 whilst SDr 1403074 also had no sprout count in week six (Table 7).

Table 8: Percentage tuber sprout count

	Sprout (%)					
Accession	6 weeks	8 weeks	10 weeks	12 weeks	14 weeks	16 weeks
SDr1403003	9.5	28.6	23.8	28.6	28.6	61.9
SDr1403004	14.3	19.0	14.3	14.3	4.8	42.9
SDr1403005	0.0	0.0	23.8	28.6	23.8	47.6
SDr1403017	14.3	42.9	38.1	42.9	61.9	57.1
SDr1403031	0.0	23.8	14.3	23.8	38.1	47.6
SDr1403074	0.0	28.6	28.6	33.3	57.1	57.1
TDR 95/19177	33.3	61.9	28.6	38.1	33.3	66.7
Grand mean	10.2	29.3	24.5	29.9	35.4	54.4
Significant level	0.061	0.007	0.5	0.072	0.07	0.67
CV (%)	126.0	52.2	62.4	69.69	60.4	33.4
LSD ($P<0.05$)	22.5	26.7	26.7	36.6	37.4	31.8

4.7 Weight of sprouts

The weight of sprout was not significant (P>0.05) throughout the storage period except on weeks eight and fourteen which showed significant (P<0.05) values. Week six showed the least (0.002) sprout weight whilst week sixteen showed the highest (0.027) sprout weight. Accessions SDr 1403005, SDr 143031 and SDr 1403074 exhibited no sprout weight in week six. The control (TDr 95/19177) showed the highest (0.053) sprout weight in week sixteen of the storage period (Table 8).

Table 9: Weight of sprout during 16 weeks of storage sprout weight

Accession	Weight (g)					
	6 weeks	8 weeks	10 weeks	12 weeks	14 weeks	16 weeks
SDr1403003	0.001	0.013	0.009	0.023	0.011	0.037
SDr1403004	0.005	0.006	0.003	0.011	0.001	0.012
SDr1403005	0.000	0.001	0.010	0.013	0.010	0.021
SDr1403017	0.005	0.012	0.016	0.016	0.028	0.012
SDr1403031	0.000	0.010	0.004	0.011	0.011	0.018
SDr1403074	0.000	0.009	0.012	0.021	0.029	0.027
TDR 95/19177	0.006	0.018	0.007	0.020	0.011	0.053
Grand mean	0.002	0.010	0.009	0.017	0.014	0.027
Significant level	0.443	0.022	0.317	0.06	0.024	0.38
CV (%)	195.1	50.4	77	32.0	65.5	81.7
LSD (P<0.05)	0.008	0.009	0.012	0.009	0.016	0.039

4.8 Weight loss of tubers

There were significant differences (P<0.05) in tubers weight loss in all the weeks except at week fourteen which was not statistically significant (P<0.05). Tuber weight greatly

reduced at week two (5.29) followed by week four (7.70), week six (12.36) and week sixteen (29.7). In general, TDr 95/19177 (control) showed the highest (44.3) weight loss among all the tuber accessions, whilst SDr 1403005 had the least (3.07) weight loss. There was a general increasing pattern as all the tubers continuously lost weight from the first week of storage to the last week of the storage period (Table 9).

Table 10: Weight loss of tubers during 16 weeks of storage

Accessions	Weight Loss (%)						
	2 weeks	4 weeks	6 weeks	8 weeks	10 weeks	12 weeks	14 weeks
SDr1403003	3.22	5.12	7.24	13.33	18.65	26.1	33.1
SDr1403004	2.51	4.04	5.71	13.07	15.52	20.7	23.9
SDr1403005	2.28	3.07	3.80	6.00	8.89	12.9	19.5
SDr1403017	2.52	4.60	8.05	11.73	19.81	25.2	33.8
SDr1403031	3.59	5.00	7.13	10.18	12.82	16.0	19.7
SDr1403074	4.32	5.15	7.31	9.28	13.36	28.0	33.4
TDR95/19177	7.69	10.07	14.65	22.96	28.81	43.3	44.3
Grand mean	3.73	5.29	7.70	12.36	16.84	24.6	29.7
Significant level	0.06	0.023	0.001	0.001	0.001	0.047	0.093
CV (%)	54.0	38.6	24.8	23.2	22.5	40.9	34.8
LSD (P<0.05)	3.52	3.58	3.35	5.03	6.64	17.64	18.10

4.9 Nutritional composition before storage

The initial nutritional profile (ash, crude fibre, fat, moisture, carbohydrates, and protein) of the seven yam accessions is presented in Table 10. There were significant differences (P<0.05) among the accessions for all the nutritional parameters analysed. The accession SDr 1403003 had the highest moisture content (73.41%) and crude ash (3.04%), but had

the least crude fat (0.53%) and carbohydrates (16.2%). SDr 1403074 had the highest crude protein (7.49 %) followed by SDr 1403003 while the least (4.60) occurred in accession TDr95/19177. Accession SDr 1403031 had the highest carbohydrates (31.87 %) and pH (6.81), followed by SDr 1403005 (31.23 %) and TDr95/19177 (28.64 %). The highest crude fat (1.68) occurred in SDr 1403004, while the genotype TDr95/19177 had the leaststst (1.88) crude ash (minerals).

Table 11: Nutritional composition of yam accessions at the beginning of study

Accessions	Variable Measured					
	Moisture content (%)	Crude Ash (%)	Crude fat (%)	Crude Protein (%)	Total CHO	PH
SDr1403003	73.41	3.04	0.53	6.83	16.20	6.60
SDr1403004	62.88	2.06	1.62	5.04	28.40	6.69
SDr1403005	55.14	1.93	0.65	6.13	31.23	6.83
SDr1403017	63.11	1.98	1.38	6.13	27.40	6.65
SDr1403031	60.77	1.98	0.78	4.64	31.87	6.81
SDr1403074	65.60	2.03	0.89	7.49	23.99	6.03
TDR95/19177	63.68	1.88	1.16	4.60	28.64	5.93
Grand mean	63.51	2.13	1.0007	5.84	26.82	6.51
Significant level	<.001	<.001	<.001	<.001	<.001	<.001
CV (%)	3.10	1.50	2.10	3.40	1.70	0.50
LSD (P<0.05)	3.39	0.05	0.04	0.34	0.79	0.05

4.10 Nutritional composition of yam genotypes after storage

Generally, nutritional composition significantly (P<0.05) varied among the yam accessions after storage. Genotype SDr 1403003 had the highest dry matter (DM) (48.66%) but had the least moisture content (50.41 %) and ash content (2.05 %). The genotype SDr 1403074 had the least dry matter (42.33 %) and crude protein (4.307%) but had the highest moisture content (57.67 %) among the genotypes. Genotype SDr 1403005 had the highest crude protein (6.594 %) and Fat (0.619 %) while the genotype SDr1403031 had the least Fat (0.233 %) and pH (5.715). The control (TDr95/19177) had the highest Ash content (3.39 %) and pH (6.022) among the yam genotypes.

Table 12: Nutritional composition of yam accessions after storage

Accessions	Variables Measured					
	% DM	% M	% CP	% ASH	% FAT	PH
SDR1403003	48.66	50.41	5.784	2.051	0.371	5.773
SDR1403004	48.35	52.03	6.404	2.406	0.243	5.938
SDR1403005	45.9	54.1	6.594	2.302	0.619	5.813
SDR1403017	46.14	53.86	5.889	2.705	0.538	5.75
SDR1403031	46.85	53.15	4.723	2.596	0.233	5.715
SDR1403074	42.33	57.67	4.307	2.163	0.598	5.898
TDR95/19177	46.58	53.42	6.56	3.39	0.248	6.022
P value	<.001	<.001	<.001	<.001	<.001	<.001
LSD	1.703	1.264	0.222	0.117	0.112	0.040
% CV	0.5	0.6	1.2	1.1	2.9	0.3

CHAPTER FIVE

DISCUSSION

5.1 Shelf-life characteristics of seven accessions of yam

The shelf life of yam varies widely across species, with *D. rotundata* cultivars having the longest shelf life (Frank, 2014). According to More et al., (2019), the length of natural dormancy varies between 4 and 18 weeks depending on the type of yam genotype**.** However, lower moisture content reduces the physiological activities in the tubers. Relatively high moisture contents, both at the start and during the storage period, most likely had a role in the rate of vulnerability to microbial assault found among the yam genotypes. The yam accessions with lower moisture content have relatively longer shelf-life as reported by Sanful et al., (2013). The present study showed that genotypes SDr 1403074, SDr 1403005 and SDr 1403031 exhibited longer shelf-life compared to the other genotypes. Moreover, genotypes SDr 1403003, SDr 1403004, SDr 1403017 and TDr 95/19177 showed no resistance to rot as observed at the13th week after storage**.** A similar observation was reported by Maalekuu *et al*., (2015) where rot affected stored yam tubers after 12 weeks of storage. The variation of shelf life among the genotypes could be attributed to different moisture content level. The occurrence of no rot in these genotypes could also possibly be due to minimal physiological activities such as dormancy, sprouting, transpiration, and respiration within the genotypes stored. Respiration is the most noticeable physiological change in the tuber during storage. This reduces the dry matter and food quality of the tuber (Osunde and Orhevba, 2009; Frank, 2014). The curing of the yam tubers before storage might have played an important role in preventing microbial attacks on the stored yam genotypes. It is reported that sweet potato shelf-life was improved upon curing before storage (More et al., 2019). Tortoe et

al., (2014) reported that temperature and humidity are the main agents in sealing off wounds on yam tubers and this occurred in an air-tight condition.

5.2 Tuber length and circumference

The size of yam tuber determines the amount of fibre it contains as well as the mineral content. Tuber length and circumference varied among the genotypes and had effect on weight loss. Genotypes SDr 140 3003 and SDr 1403031, which had the largest tuber length and circumference did not lose much weight. This is contrary to the report by Dramani, (2013) who reported that bigger tubers loss much weight than smaller ones. However, genotype TDr 95/ 1977, which had shorter tubers lost greater weight as compared to the other genotypes. Dramani (2013) reported that, the bigger the surface factors of solid objects (such as produce), the greater the surface area accessible for moisture transfer and vice versa. This means that larger tubers have a larger surface area, allowing for more moisture to be lost from the tuber in the environment. The loss of moisture on yam tubers leads to structural changes as shrinkage reduces the tuber length and circumference and this conforms with the findings of Ijabo and Uguru, (2019) who indicated that individual length and breadth of tubers decreases due to moisture loss and eventually alter its shape. In India, 11.1 to 3.70 % decrease in sphericity was observed in cold storage of some potato cultivars (Ijabo and Uguru, 2019). The accession SDr 1403003 had the highest values in both tuber length and circumference and the moisture content was not different. The high moisture content might have contributed to its highest postharvest loss compared to the control (TDr 95/19177). There were decreased trends in both length and circumference of tubers with increased storage period and this trend could be due to the shrinkage of the tubers.

5.3 Percentage sprout and weight of sprout

Several researchers including Osunde, (2008) and Imeh et al., (2012) reported that sprouting is one factor that induces weight loss and depletion of energy reserves in the tubers; since the nutrients are converted into inedible sprout. In the present study, genotype SDr 1403005 had less sprout which corresponded to its minimal weight loss during the storage period. However, genotype TDr 95/1977 had the highest sprout and this might have contributed to its greater weight loss. The susceptibility of TDr 95/19177 to sprout confirms its weight loss as more carbohydrates in the genotype is utilized for sprouting, which might have led to the decrease in crude ash content. The rate of sprouting could be affected by varietal differences and conducive conditions in the storage house. Osunde, (2008) made similar observation that at 80 % relative humidity and 16˚C of temperature, moisture loss was minimized and slowed sprouting of tubers in storage. Osunde, (2008) further stated this point by citing Adesuye (1998) that yam tubers are best stored at 15℃ which could suppress sprouting for six months. Pathological and physiological variables have been linked to postharvest losses such as rotting and sprouting. Tuber rot is caused by pathological factors such as fungi, bacteria, and parasitic nematodes, while physiological factors such as increased transpiration and rate of respiration lead to increased sprouting, desiccation, and weight loss (Osunde, 2008).

5.4 Weight loss of tubers

Weight loss is one of the major factors that causes yam tubers to deteriorate in storage due to deleterious reactions (Maalekuu et al.,2015). The weight loss observed during the storage period gives an indication of rapid tuber deterioration with an increasing trend of weight loss from first week to the last week of the storage period. In the present study genotype TDr 95/19177 which had greater weight loss also exhibited the highest postharvest loss of 19.1%. The weight loss exhibited by TDr 95/19177 could be as a result

of sprouting. This might also be due to changes in the physico-chemical characteristics of the yam tubers across the genotypes. This confirms Emenike (2010) who reported that where cellulose and hemicellulose were altered due to variety. Similar report indicates that the fibre content of tubers rises with prolonged storage, but the rate of growth varies depending on the tuber type (Afoakwa and Sefa-Dedeh, 2001). Weight loss of stored potato tubers is mainly through evaporation and sprouting (90 %) and respiration (10 %) (Walingo *et al.* 2004). Adegoke and Odebad (2017), also indicated that weight loss of yam tubers is as a result of sprouting, respiration and transpiration.

5.5 Storability of seven accessions of yam

The results from the study revealed that varietal differences contributed greatly on the shelf-life of the various genotypes. The varietal differences could be attributed to the variation in phyco-chemical properties of the genotypes. The genotypes SDr 1403031 and SDr 1403005 had the highest sugar content but did not rot during the period of storage. This could be attributed to dormancy and a well-ventilated storage barn where respiration, temperature, and relative humidity were reduced to minimum. The higher sugar content of genotype SDr 1403005, could confirm its least sprout index as sprouting could lead to the exhaustion of the high sugar content. This finding is contrary to that by Dramani (2013), who reported that the high perishability nature of Puna variety is due to its high sugar content. Sugar content in a yam genotype is influenced by variety, location and cultural treatment (Etudaiye et al., 2020). However, the SDr 1403074 genotype had a lower sugar content also did not rot during the storage period. This could possibly be due to its lower starch content.

5.6 Nutritional composition

The decreasing trend in carbohydrates, crude protein, crude ash, crude fat, and moisture content as compared to their initial values suggest physical and chemical degradation in

the stored tubers. Several reports indicate that storage greatly reduces nutritional contents in yam (Osunde and Orhevba, 2009; Sahore *et al*., 2007). This indicates dehydration of the yam genotypes during storage, which is confirmed by Dramani, (2013) who reported on 31 % rate of moisture loss in white yam stored for four months. Afoakwa and Sefa-Dedeh, (2001), also reported that the rapid dehydration of yam in storage caused polysaccharides of the cell wall to shrink as well as increase in cell wall rigidity. However, different yam genotypes have different moisture content which influences the shelf-life of the genotype. It is reported that yam variety *D. hispida* had lower moisture content after storage (Obidiegwu et al., 2020; Saleha et al., 2018) but no data showed on the effect of lower moisture on its shelf-life. In the present study, crude protein was affected by the storage across all genotypes. This finding is contrary to that of Zhang et al., (2019) who reported an increased in protein content in *Dioscorea opposita* after storage. Sahore et al., (2007) reported that tannins could be the reason for decrease in protein content as they form complexes with protein and thus reducing the amount of protein present. In the present study, the fat and carbohydrates levels slightly decreased while ash content increased after storage. This finding is in line with that of Osunde, (2008) who reported decreased in carbohydrates in yam tubers after three months of storage. It is reported that physiological activities such as conversion of starch to sugar and respiratory losses due to the conversion of sugar into carbon dioxide (Osunde, 2008; Sahore et al., 2007) could be the main reason for the decreased in carbohydrates. Dry matter content increased as well as the pH of the yam genotypes. This could be attributed to decreases in the moisture content of the yam genotypes.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Yams are generally abundant and sold cheaply after harvest, but later become scarce and expensive due to rot and lack of storage facilities. The problem of postharvest losses of yam spans across all yam producing regions of Ghana due to poor storage structures. Currently postharvest losses in yam hover around 10-60% depending on the variety, handling condition, duration of storage, and other factors. This study demonstrates that all the 7 accessions evaluated had less than 20% losses under farmer storage conditions. The above results have demonstrated that all the seven tested accessions stored well throughout the experiment with tuber circumference, tuber length, percentage sprout count weight loss, tuber decay and shelf-life were affected by yam genotype while sprout weight was affected by the yam accessions. However, for better storability and decreased postharvest losses, accessions SDr1403005, SDr1403031, and SDr1403074 were outstanding. These three accessions exhibited minimal weight loss, reduced perishability, and maintained their wholesomeness over the period of storage. These accessions can therefore contribute to food security in northern Ghana if adopted by farmers.

Nutritional composition of all the accessions before and after storage revealed a decreased trend in carbohydrates, crude protein, crude ash, crude fat, and moisture content after four months of storage.

6.2 Recommendations

- From the study, accessions SDr 1403074, SDr 1403005, and SDr 1403031 showed no rots and thus had the longest shelf-life and are therefore recommended for farmers in the Guinea Savanna Ecological Zone for cultivation.

- Nutritionally, all the yam genotypes are recommended for consumers however, with respect to crude protein and minerals accessions SDr 1403005 and SDr 1403017 were higher and are recommended genotypes.

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APPENDICES

Appendix 1: Analysis of variance dry matter

Variate: %_DM

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATION stratum	2	0.6653	0.3327	0.36	
REPLICATION.*Units* stratum					
SAMPLE_ID	6	78.1365	13.0228	14.22	<.001
Residual	12	10.9904	0.9159		
Total	20	89.7923			

Appendix 2: Analysis of variance for moisture content

Variate: %_M

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATION stratum	2	1.2158	0.6079	1.20	
REPLICATION.*Units* stratum					
SAMPLE_ID	6	89.2501	14.8750	29.48	<.001
Residual	12	6.0543	0.5045		
Total	20	96.5202			

Appendix 3: Analysis of variance for crude protein

Variate: %_CP

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATION stratum	2	0.06278	0.03139	2.02	
REPLICATION.*Units* stratum					
SAMPLE_ID	6	14.85470	2.47578	159.62	<.001
Residual	12	0.18612	0.01551		
Total	20	15.10361			

Appendix 4: Analysis of variance for crude ash

Variate: %_ASH

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATION stratum	2	0.011642	0.005821	1.35	
REPLICATION.*Units* stratum					
SAMPLE_ID	6	3.614041	0.602340	140.10	<.001
Residual	12	0.051594	0.004300		
Total	20	3.677276			

Appendix 5: Analysis of variance for fat

Variate: %_FAT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATION stratum	2	0.001940	0.000970	0.24	
REPLICATION.*Units* stratum					
SAMPLE_ID	6	0.548038	0.091340	23.05	<.001
Residual	12	0.047543	0.003962		
Total	20	0.597521			

Appendix 6: Analysis of variance for pH

Variate: PH

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REPLICATION stratum	2	0.0041214	0.0020607	4.08	
REPLICATION.*Units* stratum					
SAMPLE_ID	6	0.2244810	0.0374135	74.06	<.001
Residual	12	0.0060619	0.0005052		
Total	20	0.2346643			