KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

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EFFECT OF TRADITIONAL STORAGE METHODS AND PERIODS ON CASSAVA ROOTS (*Manihot esculentus,*Crantz) ON THE YIELD AND NUTRITIONAL COMPOSITION OF UNFERMENTED FLOUR

BY

ADU-FAMEAH MATTHEW BRIGHT

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ADU-FAMEAH MATTHEW BRIGHT

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MAY, 2016

DECLARATION

I hereby, declare that the work reported in this thesis except where otherwise indicated, is my own original research. This thesis has not been submitted for any examination or degree elsewhere. This research does not contain any other person's 'information being it a data, pictures or graphs unless specifically acknowledged as being sourced from other persons.

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DEDICATION

To the Almighty God who protected me through this program and to my mother Mamma Cecilia Cobbina, my wife, Vivian Nipah, and other family members who always stood by me through my educational journeys.

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ABSTRACT

Cassava (*Manihot esculenta*, Crantz), has attained considerable importance as a dominant staple food as well as an industrial raw material at a global level due to its numerous uses of the starch-rich roots. Several traditional storage methods have been devised for cassava roots due to the physiological deterioration that set in 2-3 days after harvesting, followed by microbial deterioration 3-5 days thereafter. However, the adoption level of these methods in general has been very low. It is therefore imperative to consistently investigate the appropriateness of some traditional storage methods of cassava roots meant for unfermented flour production. This study was, therefore conducted at the Ministry of Food and Agriculture, Enchi, Ghana, to determine the effect of different traditional storage methods and periods of cassava roots on the yield and nutritional composition of unfermented flour. Flesh cassava root of 10 kg each were arranged in woven polypropylene bags, plastic containers, trenches and wooden boxes and stored for 0, 7 and 14 days. The flour produced was analysed for proximate, minerals (calcium, iron and phosphorus), and percentage yield at the Department of Horticulture, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. This study revealed a varying impact of storage methods over the storage days. The flour produced from plastic container on storage Day 7 showed significantly (p =0.01) the least (6.56%) moisture content, and it is the method of choice. Plastic container method on storage Day 14 also showed appreciable levels of calcium and iron contents of flour as 0.165 g/100g and 35.55 mg/kg, respectively. The root stored in trench recorded the highest flour yield of 19.17% and 18.17% after 7 and 14 days of storage, respectively. This was significantly lower than the flour yield produced on storage Day 0 as 22.2%. It could, therefore, be inferred from this study that, for best

results, in flour yield and nutrients, storage of fresh cassava roots for cassava flour should not exceed 7 days in plastic container.

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LIST OF ABBREVIATIONS

AFLP	-	Amplified Fragment Length Polymorphism
AOAC	-	Association of Official Analytical Chemists
CIAT	-	International Centre for Tropical Agriculture
CSIR-FRI	-	Council for Scientific and Industrial Research – Food Research Institution
EfDI	-	Enterprise for Development International
FAO	-	Food and Agriculture Organization
HQCF	-	High Quality Cassava Flour
IITA	-	International Institute for Tropical Agriculture
MoFA	-	Ministry of Food and Agriculture
NRI	-	Natural Resources Institute
PPD	-	Postharvest Physiological Deterioration
TTA	-	Total Titratable Acidity

CHAPTER ONE

1.0 INTRODUCTION

Ghana is endowed with a wide range of climatic conditions which provides opportunities for growing a large number of crops including roots and tubers. Cassava (*Manihot esculenta,*Crantz), is one of the major root and tuber crops grown in the tropics (Philips *et al*., 2004) and it provides large amount of calories to over five hundred (500) million people globally (Mroso, 2003). It has attained considerable importance as a dominant staple food as well as an industrial raw material at a global level due to its numerous uses of the starch-rich root (UNIDO, 2006).

Nigeria is ranked first as world-wide producer of cassava, followed by Indonesia, with Ghana rated fifth and third in Africa (FAOSTAT, 2012). The crop contributes immensely in the field of agriculture in the developing countries with specific emphasis on sub-Saharan Africa, because it is cultivated widely and has the ability to withstand drought, pests and poor soil conditions (Wanapat *et al*., 2006). Cassava is a perennial crop that can stay in the soil even after maturity and therefore can be harvested when needed. Its wide harvesting windows allow it to serve as a famine reserve and are invaluable in managing labour schedules. It assists the resource-poor farmers because it can be cultivated as either subsistence or a cash crop (Stone, 2002).

Unfermented Cassava Flour is smooth, odourless, white or creamy, bland with no gluten. Commercial production of unfermented cassava flour is relatively new in

Africa. As a result of increase in the price of the wheat in the international market and unfavourable exchange rates in West Africa, unfermented cassava flour was introduced and is now gradually gaining popularity in the sub-region. It has contributed appreciably to cassava industrial revolution especially in Nigeria and Ghana (Sanni *et al*., 2008), with enormous potentials in the other countries within the Sub-region. The product has been found to be suitable for making a variety of pastries, whole or in the composite forms (cakes, cookies, doughnuts and bread) and convenience foods. It is also an acceptable raw material for the manufacture of industrial items like textiles, plywood, paper and so on (Dziedzoave *et al*., 2006).

A study has shown that unfermented cassava flour has gained highest market potential as a substitute to wheat in food and for the production of paper board industry (Day *et al*., 1996). The largest market potential for cassava flour in the medium- to- long-term in Ghana lies in food applications (Day *et al*., 1996) and could potentially replace huge amounts of wheat flour presently used in the industries and other food items such as ‘kokonte’ and ‘fufu’

A research conducted at the Industry and Technology Fair held in Accra from February, 28 to March 10, 1997, obviously indicated that 20% of a composite cassava flour inclusion rate was accepted widely by the general public compared with 100% wheat flour. Its wide consumption is ascribed to its relatively long shelf life compared to other food products from cassava, as well as its ease of preparation for eating (Sanni *et al*., 2008).

The pre-process is the main problem of cassava utilisation on an industrial scale.

Physiological deterioration occurs in cassava roots 2-3 days after harvesting, followed by microbial deterioration 3-5 days thereafter (Akingbala *et al*., 2005). This deterioration is either primary or secondary. The primary deterioration is physiological that involves internal discolouration and the secondary deterioration is primarily caused by microorganisms leading to fermentation and softening of the roots tissue (Andrew, 2002). The physiological deterioration is economically more important than the microbial deterioration due to the reduction in economic value of the crop and most especially for production of cassava flour, 'gari' and 'fufu'.

Several traditional storage methods (leaving roots in the soil after maturity, storing in water, storing in trench and so on), which seems to be more viable and economical have been devised to control the cassava deterioration. The adoption level of these methods in general has been very low prior to processing the root to key products such as flour,''gari' and 'fufu'. It is therefore imperative to consistently investigate the appropriateness of some traditional storage methods of cassava roots meant for unfermented flour production. The study was therefore carried out to determine the effect of different traditional storage methods and periods of cassava roots on yield and nutritional composition of unfermented flour.

The following objectives were achieved by the study:

1. to determine the effect of four different traditional storage methods and three storage periods of cassava roots on percentage unfermented flour yield;
2. to determine the effect of four different traditional storage methods and three storage periods of cassava root on proximate and essential minerals (iron, calcium and phosphorus) of unfermented flour; and

3. to evaluate the most suitable traditional storage method and storage period for the production of unfermented cassava flour.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 CASSAVA

2.1.1 Origin of Cassava

The original home of cassava was probably in Brazil and Paraguay and was introduced to the African soil by the Portuguese traders from Brazil .The Portuguese grew the crop at the premises of their trading ports, forts and castles to feed themselves and the slaves especially in the Gold Coast, (now Ghana) (Korang – Amoakoh *et al*., 1987). At the middle part of the 18th century, the crop had received much attention, widely grown and used by the people of the coastal plains. Generally, most local dishes in Africa are mainly prepared from cassava.

2.1.2 Taxonomy of Cassava

Cassava belongs to the spurge family, Euphorbiaceae, with several commercial species. It is a dicotyledonous plant and belongs to genus *Manihot*; sub - species *Manihot esculenta* Crantz and species *esculenta* (Allem *et al.,* 2001).It is the only species from the genus that is commonly grown for food uses (Nassar and Ortiz, 2006). The genus, *Manihot* has about 98 species grouped into 19 taxonomic sections. There are no genetic and cytological barriers in the species of the *Manihot* genus (Nassar and Ortiz, 2006), thus there can be interspecific crosses between species within the genus (Nassar and Ortiz, 2006).

2.1.3 Morphology of Cassava Plant

Cassava plant is a shrubby woody, short – lived perennial, growing to a height of 300cm or more with an erect globurous stem marked by prominent knobbly leaf scars with varying degrees of branching (IITA, 2001). Varieties of cassava can be grouped based on their flowering habit as non-flowering, poor flowering, fairly good flowering and profuse flowering. Morphologically, the plant can be distinguished by their distinct features as leaf size, colour, plant height, branching type, growth periods, tuber shape and the yield quality (IITA, 2001).

The leaves are spirally arranged on the stem, palmately compound with long petioles subtended by small deciduous stipules. The leaves are usually dark green but red, yellow and various shades of purple pigmentation occur in the foliage (IITA, 2001). The fruit develops as a result of cross pollination. It is a globular capsule, trilocular, 1.0 to 1.5 cm in diameter with six straight aristae (CIAT, 1981).
Each locus contains a single carunculated seed (El-Sharkawy, 2012).

The root comprises adventitious root which later develop into fibrous roots system that anchors the plant firmly in the soil by absorbing water, minerals and other rich nutrients from the soil (ITTA, 2001). Apparently all the roots have that ability, but diminishes considerably when roots become tuberous. Only a few fibrous roots, generally fewer than ten, become tuberous on each plant: most remain fibrous and continue functioning as nutrient-absorbing roots. The number of tuberous roots is generally determined in the crop’s early growth stages. Tuberous roots of cassava are morphologically identical to the fibrous roots (IITA, 2001). The essential difference is that the root’s direction of growth changes from longitudinal to radical when starch accumulation begins. However, this does not imply that the root does not continue growing lengthwise (IITA, 2001).

The tuberous roots of cassava result from the secondary growth of the fibrous roots. This means that the soil is penetrated by thin roots, and that enlargement of the roots begins only after these penetrations have occurred. In the centre of the root are rows of hard vessels of xylem parenchyma, which forms the root's central fibres. The toughness, length and width of these fibres are varietal characteristics influenced by climatic conditions and the plant's development process (CIAT, 1981).

2.2 NUTRITIONAL VALUE OF CASSAVA ROOT

The composition of cassava greatly depends specifically on tissues such as root and leaf which is accompanied by many factors as geographical location, varietal and age differences of the plant and environmental conditions. A matured cassava plant which contains approximately 50% roots and 6% leaves plays a significant role nutritionally as parts of cassava (Tewe and Lutaladio, 2004). Nutritionally, cassava root is of great importance because it is the main part of the plant used as food in many developing countries.

Cassava root is energy reserved crop and thus shows very efficient carbohydrate production per hectare. The crop contributes beyond two hundred and fifty thousand (250, 000) calories /hectare/day, which ranks it before some important cereals such as maize, rice, sorghum and wheat. The crop is a physiological energy-dense with high carbohydrate content, which ranges from 32 - 35% on fresh weight (FW) basis, and from 80% - 90% on dry matter (DM) basis. 80% of the carbohydrates obtained is in the form of starch (Gil and Buitrago, 2002). Rawel and Kroll, (2003) also revealed that 83% of the carbohydrate produced is amylopectin and 17% is in the form of amylase. Usually the varietal and the age differences of the cassava root determine the crude fibre content. Normally, the fibre component is not beyond 1.5% in fresh cassava root and 4% in cassava flour (Gil and Buitrago, 2002). The protein content is in the range of 1% to 3% on DM basis and between 0.4 and 1.5g/100g FW (Buitrago, 2002). The roots of cassava have calcium, iron and phosphorus contents of 1.6mg, 0.27mg and 27mg respectively with vitamin A content of 20.6mg.

Table 2.1: Proximate composition of fresh cassava roots

Component	Values
Moisture (g/100g)	59.4
Carbohydrates (g/100g)	38.1
Protein (g/100g)	1.10
Fat (g/100g)	0.47
Crude fibre (g/100g)	1.10
Ash (g/100g)	0.70
Calcium (mg/100g)	0.10
Phosphorus (mg/100g	0.15
Iron(mg/100g)	1.7

Buitrago, 2002; IITA, 2001.

2.3 POSTHARVEST PROBLEMS

Generally, the shelf - life of cassava accepted by the public is within the period of 24 - 48 hours after harvest. Notably, there are two main types of postharvest deteriorations which comprised primary deterioration and secondary deterioration. The primary deterioration is physiological that involves internal discolouration and is the initial cause rendering the product unwholesome hence making it unacceptable to consumers. The secondary deterioration is primarily caused by microorganism leading to fermentation and softening of the roots tissue (Andrew, 2002).Visible signs of postharvest physiological deterioration (PPD)are vascular streaking with blue or black discolouration rendering the roots unwholesome, reduction in taste and are rejected by marketers. This initial deterioration is physiological and biochemical and does not involve microorganism (Andrew, 2002).

Physiological deterioration is a process considered to resemble a typical wounding response in which the healing process is inadequate (Beeching *et al.,* 2002). Physiological deterioration shares features of wound responses in other plants, increased activity of enzymes such as phenylalanine ammonialyase and polyphenyl oxidase, the synthesis of lignin and suberin or secondary metabolates from the phenylpropenoid or terpenoid pathway and the synthesis of free radicals. There is also accumulation of phenolic compounds, including coumarins, catechins and flavonoids (Buschmann *et al.*, 2002).

2.4 LOW- COST TRADITIONAL STORAGE METHODS OF CASSAVA ROOTS

The Natural Resources Institute (NRI) collaborated with the International Centre for Tropical Agriculture (CIAT) to gain an understanding of the process of physiological deterioration. Several techniques have been devised to control the physiological deterioration (Osunde and Fadeyibi, 2011).

2.4.1 In- Ground Storage Technique

Cassava root is commonly preserved by leaving the crop in the soil until it is needed. This flexibility in harvesting is one of the paramount features of the root when used for food security. Cassava roots have no optimum harvest age after which there is a loss in yield. At the same time the roots become woody and there can be impairments to flavour. During storage, there is the danger that roots will be infested by pathogens (Lancaster and Coursey, 1994).

There is also the problem that this form of storage ties up large amounts of the land that could be used to grow other crops. This is a significant problem in densely populated areas (Knoth, 1993). This technique seems to have been popular in many countries especially in South America, and has been developed in other areas where cassava is largely grown.

2.4.2 Pruning Technique

Farmers normally store cassava roots harvested with a short length of stem attached in order to delay deterioration. Studies show that, pruning delays the onset of PPD as compared to unpruned plants (Oirschot *et al.*, 2000). Further research revealed that sensory ratings for texture, flavour and general acceptability were higher in roots from unpruned plants, while crude fibre and moisture contents were lower during storage. Again, another research indicated that the roots of a cassava variety could be stored for a longer period of time when pruned two (2) weeks before harvest. Oirschot *et al., (*2000) reported that, pruning the aerial parts of cassava to 20 to 30 cm above the soil 2 to 3 weeks before harvest improved keeping qualities without any yield reduction.

2.4.3 Clamp Silo Technique

Studies have shown that cassava roots could be arranged on a layer of sawdust in conical heaps weighing between 300 and 500 kg. The roots were covered with another sawdust and finally with soil and openings were left for free flow of air. The moisture content of the saw-dust requires careful control as too much moisture promotes fungal growth whereas too little also hastens deterioration (Rickard and Coursey, 1981). These methods are based on the process of curing, a common method for enhancing the storage life of other roots crops at high temperatures (25°C - 40°C) and relative humidity (80% to 85%). This system is possible to store roots for up to 4 weeks without significant loss of weight or microbial deterioration (Westby and Gallat, 2002).

2.4.4 Pit Storage Technique

Cassava roots in pits containing sand or soil at 15% moisture content has been conducted in India. 80 - 85% of the roots were recovered undamaged after 2 months storage duration (Balagopalan, 2000). After 2-month storage of cassava roots, approximately 15% -20% of their starch contents were lost which was equivalent to 1 week of storage under ambient conditions. There was also drastic reduction in cyanogen content of cassava root (Rickard, and Coursey, 1981)

2.4.5 Wooden crates technique

Cassava roots were stored in wooden crates containing moist wood-shaving. If the wood-shaving is too moist it triggers fungal development and if too dry the roots deteriorate quickly. Studies showed that lining the crate with plastic foil prevents drying out of the wood-shaving resulting in storage period of 4 - 8 weeks (Rickard and Coursey, 1981).

2.4.6 Woven Bags (Rice or Fertilizer Sacks) Technique

Cassava roots were stored in tightly woven bags and 7 - 10 days storage times were achievable that were adequate for Ghanaian marketing systems (Gallat *et al.*, 2008). The technique was evaluated with a number of potential stakeholders and it was found to be particularly useful for local food retailers and itinerant traders. The techniques have subsequently transferred to Tanzania (Westby *et al.*,2002).

2.4.7 Polyethylene Bags Technique

This method has also been reported to delay PPD hence prolong the shelf - life up to a month due to the high relative humidity (RH) inside the polythene bag which reduces respiration and transpiration (Ravi *et al.*, 2006).

2.4.8 Plastic Bags or Plastic Film Wraps Technique

Practically, this storage technique is considered to be the most appropriate method of storing cassava roots purposely for the urban markets (Crentsil *et al.*,1995). A number of studies have proved that cassava roots treated with recommended insecticides and stored in an airtight plastic bag can be kept for two to three weeks (Osunde and Fadeyibi, 2011).

2.4.9 Heaping and Watering Technique

Cassava roots are arranged in conical shape and watered daily to keep them fresh for a period of 4to 6 days in most of the West African countries especially Nigeria. This technique seems to have been widely adapted by farmers. A research conducted in Uganda and Mozambique revealed that even in recent times roots are mainly stored by putting in water for a few days (Essers *et al.*, 1995a).

2.5 USES OF CASSAVA

2.5.1 Human Food

Cassava root can be utilized in several ways. The roots and leaves of cassava are used for human consumption (Buitrago, 2002). The edible part of the root constitutes about 85% of the total weight of the root and taste similar to potato when boiled (Alves, 2002).In Africa, "mash" fufu, is widely consumed by

pounding and sieving cassava to make flour which is put into hot water. This is particularly popular food in Nigeria, Ghana and the Democratic Republic of Congo. Gari is a type of porridge which is white cassava flour prepared from fermented cassava roots. The gari is tasteful when prepared with cold water, sugar and milk with little roasted groundnut added (Sanni *et al*., 1992)

In the West, cassava is mostly used in the form of tapioca which is flavourless, starch ingredient used as thickening agent in foods. It is gluten - free and therefore used in many gluten - free foods. Tapioca is also used to prepare bubble tea which is a popular drink in Taiwan (Sanni *et al*., 1992).

2.5.2 Animal Feed

Cassava roots can be processed into any suitable form to feed a wide range of farm animals. Ina form of hay, cassava is harvested at the tender age, normally when it grows to a height of about 30 cm - 40 cm above ground. It is dried in the sun usually for a maximum period of 24 – 48 hours until the product attains final dry matter content less than 85% (Westby and Gallat, 2002).

Generally, hay contains as high as 25% and between 1.5% - 40% of crude protein and condensed tannins (crude) respectively. It contributes immensely especially in the diet of ruminant animals because of its indispensable roughage as direct feeding or as a protein source concentrate mixture (Wanapat *et al*., 2005).Cassava root can also be processed in to flour which is fortified with other essential vitamins, minerals and other rich ingredients to feed other forms of farm animals including poultry (Buitrago, 2002).

2.5.3 Industrial Use

Cassava has gained high recognition globally due to its versatile applications especially in the industries. Generally, cassava standout because of its primary and secondary products such as cassava flour, crude ethanol, native starch, chips and pellets (animal feed), glucose syrup, extra neutral alcohol, noodle, bakery and so on (Buitrago, 2002).

Industrially, cassava flour is used in making bread as partial or total replacement of wheat 100% cassava flour is currently used in the bakery industry in the preparation of pastries and confectioneries. Again, cassava is used as a raw material in the pharmaceutical, brewery, glues and adhesives industries (EfDI – Technoserve, 2005).Cassava flour which is a product of cassava root can be mixed with eggs and then cooked in a soup or boiled water to prepare noodles as a rich food for people (Sanni and Akoroda, 2005). In addition, cassava base adhesive, for example, dextrin based adhesives are supplied depending on their specifications and requirements. The dry dextrin adhesives are packed as a pre-gel adhesive and exported especially to the Europe and America (Sanni and Akoroda, 2005).

2.6 PROCESSINGTECHNIQUES OF CASSAVA ROOT

Cassava undergoes postharvest physiological deterioration (PPD) once the roots are confined from the primary plant. They are massive with around 70% dampness content. Consequently, the root must be handled into different courses so as to expand the rack - life of the items, ease transportation, decrease cyanogenic possibilities and enhance taste (Westby and Gallat, 2002). Handled cassava roots can be enhanced healthfully through fortress with other protein - rich harvests.

Generally, different systems are utilized to process cassava root into numerous items and used in various routes base on nearby traditions and preferences. Traditional cassava root handling routines utilized as a part of Africa may most likely be begun from Tropical America, especially north-east Brazil and may have been adjusted from indigenous methods for preparing yam tubers. The handling activities comprise peel removal, bubbling, steaming, chipping, grinding, drenching or leaking, maturing, beating, squeezing, drying and processing (Nweke, 1988).

2.6.1 Importance of Processing Cassava

Cassava is the most perishable among the root and tuber crops and can deteriorate within two or three days after harvesting. The high moisture content characterized by cassava roots make it difficult to store for any length of time. They are also bulky and difficult to handle and transport to distant market hence its processing needs much to be desired. Processing the root into any form of food, involves peeling and up to about 83% of the cyanide content is reduced to a level which is acceptable and safe for consumption (Westby and Gallat, 2002). Processing renders the bitter cassava less harmful by detoxifying and removing cyanogenic content, hence extending the useable period than its raw form (Westby and Gallat, 2002). Again, food wastage is reduced by making the crop available all year round. For domestic consumption, cassava processing is a rural enterprise which adds value to the product and increases the marketing opportunities (Westby and Gallat, 2002).

2.7 CASSAVA DRYING TECHNIQUES IN GHANA

Drying is a technique in preserving food which involves the removal of moisture content to an acceptable form. It is identified to be one of the major challenges in cassava production industry. Drying inhabits the growth of bacteria, yeast and mould through the removal of water. Moisture is traditionally removed through evaporation (air drying, sun drying, smoking or wind drying). Drying aims at reducing the moisture content of cassava to less than 15%. The recommended moisture content varies from the type of final product ranging from 9% to 15%

(Wenlapotit, 2004 and IITA, 2005). According to IITA, (2005), four main factors were seen influencing the drying of cassava (chips, flour and starch).These factors include: temperature, airflow, humidity and tumbling frequency.

Cassava drying is done at temperature between 40°C and 60°C, at temperature of about 60°C gelatinization of cassava starch sets in (FAO, 2000). While drying, hot dry air needs to flow through the dryer so as to pick up moisture from the product being dried. Humidity is low in a hot summer days hence the dry atmospheric air can be used for effective drying. However, the drying potential can be enhanced through pre heating/drying of the drying air. The pre heating may be imperative in the wet season. When drying, the sliced or chipped cassava pulp is placed on a non - perforated material, usually plastic sheet or concrete floor, thus, products at the base will not dry; hence frequent tumbling helps expose the products giving even drying. Four methods for cassava drying were identified by IITA (2005) as sun drying, artificial, rotary and flash drying.

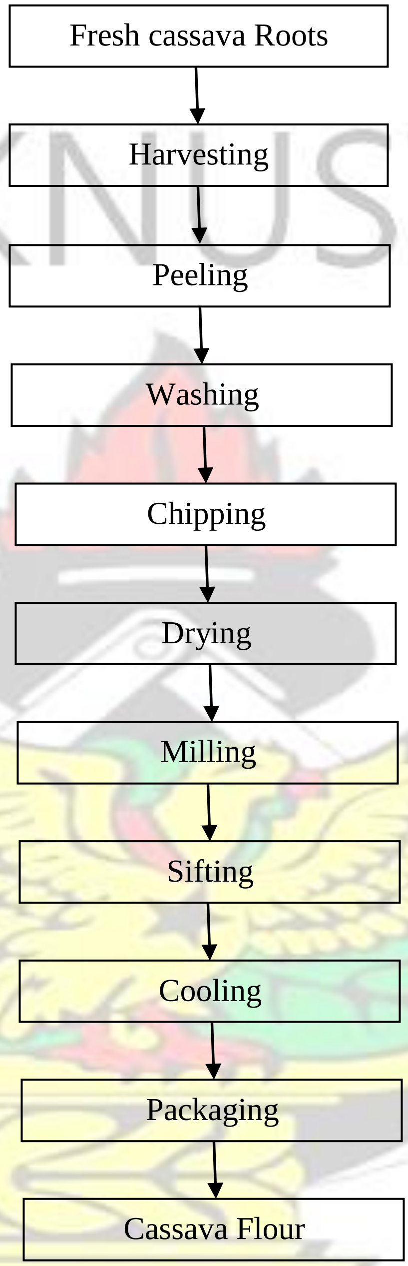
Sun drying is where cassava mash or sliced pulp placed on either a plastic sheet or a concrete floor and exposed to the sun for drying. It involves turning depending on the nature of the product. Sun dried products are the most common types of processed cassava products in Africa (Westby and Gallat, 2002).

Artificial drying is where a controllable source of energy is used for drying operations. Further classification to artificial drying is brought about by the source of energy used in the heating of the drying air. Such energy sources include electricity, biomass, solar, other renewable energy sources and fossil fuels (IITA, 2005).

2.8 PRODUCTIONOF UNFERMENTED CASSAVA FLOUR

A fresh harvested cassava roots of 10-12 months old should be selected and processed within 24 hours (Dziedzoave *et al*., 2003). Healthy roots with no bruises and damages should be carefully selected and peeled manually with a sharp stainless steel knife. However, mechanical peelers are used by commercial processors. The peeled cassava roots are washed thoroughly under portable running water with a sponge to remove any dirt and impurities. White bright colour is an important attribute desired by consumers. The chips are milled, cooled and sieved by means of a motorized flour sifter fitted with a 250 um screen in order to obtain smooth flour with a uniform particle size. Finally, the flour is kept in a suitable packaging material such as polypropylene sacks for safe storage (Dziedzoave *et al.*, 2003).

Figure 2.1: Traditional flow chart for the production of unfermented high quality cassava flour (Nwosu *et al.*, 2014)



Some objective quality parameters of High Quality of Cassava Flour (HQCF) required by the industry for food uses is presented in Table 2.2.

Table 2.2: Proximate, physical and chemical quality characteristics and requirement of HQCF for food uses

Characteristics	Quality levels
Protein	1 - 3%
Fat	0. 6%
Fibre	1 - 4%
Ash	1 - 2.8%
Moisture	8 - 10%
Carbohydrate	80 - 90%
Calcium	10. 60mg/100g
Phosphorus	3.5 mg/100 g
Iron pH	29 - 40 mg/100g
Total titratable acidity(as lactic)	6 - 7. Less than 0.25%

(Dziedzoave *et al.*, 2003, Dziedzoave *et al.*, 2006).

2.9 USES OF UNFERMENTED CASSAVA FLOUR

Unfermented cassava flour is white, smooth, flavoured and odourless cassava flour. Its production process was initially developed at the International Institute for Tropical Agriculture (IITA) in Nigeria as an alternative to imported wheat flour for the food and non - food industry and the technology is now used in some cassava growing countries including Ghana (Falade and Akingbala, 2008). Immediately after harvest, healthy roots are selected for onward production of unfermented cassava flour.

The suitability of the flour can also be measured in the production of plywood, textiles, paper board, adhesives, gum, glucose syrup and pharmaceutical drugs. However, the most important potential used is valued in composite with flour in high - grade foods such as bread. The preparation of unfermented cassava flour differ far from the preparation of traditional fermented cassava flour such as gari, agbelima and tapioca by the absence of extensive fermentation that gives a low pH and a sour taste, unacceptable for the inclusion in industrial products (Dziedzoave *et al*., 2006).

2.10 FUNCTIONAL PROPERTIES OF UNFERMENTED CASSAVA FLOUR

Bulk density, according to Sumbramanian and Viswanathan, (2007) is defined as the ratio of weight of the flour to the flour volume in gramme per centimetre cube. It reveals the heaviness of the flour samples. Bulk density of the flour increases with increase in starch content (Nwanekezi, 2009). Bulk density is an indicative parameter to determine the space the flour would occupy and the amount of packaging material required (Fagbemi *et al.*, 1999).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 LOCATION OF THE EXPERIMENT

The experiment was carried out at the premises of Ministry of Food and Agriculture, Enchi in the Western Region of Ghana. The experiment was conducted in January

2015.The laboratory analysis of the unfermented cassava flour was carried out at the Department of Horticulture, School of Agriculture and Natural Resources, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

3.2 DATA COLLECTION

Approximately two hundred and fifty (250 kg) of cassava roots of Twelve (12) month Old “Ampong”, a hybrid variety, released by Centre for Scientific and Industrial Research (CSIR) to MoFA in Jomoro, in Nzema. It is predominantly used by the farmers in the study area, Aowins, in Western Region, Ghana. The roots were carefully harvested manually from a farm of Local farmer in Enchi. Approximately 10kg of the roots was used as experimental Unit. Immediately after harvest, 10 kg of the roots were weighed and processed into unfermented cassava flour using the traditional method as described by Nwosu *et al.* (2014).

The remaining roots were divided into twenty - four (24) groups of about 10kg each. They were stored in the four storage methods of woven polypropylene bags, trenches, wooden boxes and plastic containers. The woven polypropylene bag was of 0.30 mm thickness, the trench was of 0.7 m long, 0.5 m wide and 0.5 m deep, the wooden box was of 0.7 m long, 0.5 m wide and 0.5 m deep while the plastic container was of 0.6 m high and 0.4 m wide. The roots were carefully arranged into the various storage media and well labelled. In between the layers of the roots stored in the trench and wooden box were moist wood shaving and again covered with another moist wood shaving and finally covered. On Day 7 storage, the first set were obtained and processed into unfermented cassava flour and on Day 14 storage, the second batch were also obtained and processed same. The unfermented cassava flour were analysed for proximate, mineral composition and percentage yield. The samples were at ambient temperature of 30 ± 2^{o}C.

3.2.1 Sample Preparation

Cassava roots were processed into unfermented flour on the day of harvest and on Days 7 and 14 of storage using the traditional unfermented flour processing method as described by Nwosu *et al.* (2014) (Figure 2). The peel was carefully removed from the pulp with a stainless kitchen knife. The pulp was washed under running tap water to remove all dirt. The pulp was chipped manually with stainless steel knives into varying sizes of about 1 – 5cm. The chipped pulp was sun - dried on a raised woven raffia mat for a period of 6 - 8 days at ambient temperature of 30 ± 2°C. The dried cassava chips were milled into flour using an electric milling machine. The flour was allowed to cool and then sieved in order to obtain smooth flour with a uniform particle size. Finally, the flour was weighed to determine the flour yield and packaged afterwards. The yield of unfermented cassava flour was measured as the percentage of the weight of the unpeeled fresh root on a dry matter basis.

3.3 EXPERIMENTAL DESIGN

The experimental design used was a 3 x 4 Factorial Completely Randomized Design (CRD).The experiment was replicated three times.

3.4 TREATMENTS

Two factors were used in the experiment. The first factor comprised three storage periods: 0 day storage period, 7 days storage period and 14 days storage period. The second factor comprised four storage methods: woven polypropylene bag, trench, wooden box and plastic container of fresh cassava roots.

3.4.1 Treatment Combinations

The treatment combinations employed in the experiment involved:

- Woven polypropylene bag storage method + 0 day storage period.
- Woven polypropylene bag storage method + 7 days storage period.
- Woven polypropylene bag storage method + 14 days storage period.
- Trench storage method + 0 day storage period.
- Trench storage method + 7 days storage period.
- Trench storage method + 14 days storage period.
- Wooden box storage method + 0 day storage period.
- Wooden box storage method + 7 days storage period.
- Wooden box storage method + 14 days storage period.
- Plastic container storage method + 0 day storage period.
- Plastic container storage method + 7 days storage period.
- Plastic container storage method + 14 days storage period.

3.5LABORATORY ANALYSIS

3.5.1 Proximate Analysis

Proximate analysis of food is the determination of the major components of food which comprised moisture, ash, carbohydrate, fat, fibre and protein. In determining the proximate composition of the flower, standards of AOAC (2010) and methods was used.

3.5.1.1 Determination of percentage Moisture Content of unfermented cassava

Flour

Moisture can or porcelain crucible was weighed. Triplicate 2 g of granular samples were weighed with the balance and then transferred into the porcelain crucible and were allowed to dry overnight in an air oven at 110^{o}C for 24 hours. Crucibles plus samples were allowed to cool in a desiccator and then re-weighed.

<u>Calculations</u>

(A + B) – A = B

(A + B) – (A + C) = B - C = D   % Moisture = D/B x 100

Where A = crucible wt., B = sample wt., C = dry sample wt., D = moisture wt.

3.5.1.2Determinationof Percentage Ash of Unfermented Cassava Flour Ash crucibles were removed from oven and then placed in desiccators to cool and weighed. Triplicate 2.0 g of the samples were weighed with the balance and transferred into porcelain crucibles in duplicate. The sample was put into furnace for 2 hours at 600^{o}C and was allowed to cool below 200^{o}C and was maintained for 20 minutes. The crucibles were placed in desiccators with a stopper top, allowed to cool and then weighed.

<u>Calculations</u>

(A + B) – A = B

(A + C) - A = C

% Ash = C/B x 100 where A = crucible weight, B = sample weight, C = ash weight.

3.5.1.3 Determination of Percentage Carbohydrate Content of unfermented

Cassava Flour

The calculation of carbohydrate is made after completing the analysis for moisture, ash, crude fibre, ether extract (fat) and crude protein.

% carbohydrate = 100% - [% moisture + %ash+ % crude fibre + % ether extract (fat) + % protein}

3.5.1.4 Determination of percentage Fat content of unfermented cassava Flour

Triplicate 2.0 g of the samples were weighed and then poured into a folded piece of filter paper to hold the samples. Second filter papers were wrapped around and were left open at the top like at himble. A piece of cotton wool was placed at the top to evenly distribute the solvent as it drops on the sample during extraction. Sample packet was placed in the butt tubes of the Soxhlet extraction apparatus. Extraction flask was also placed in an oven for about 5 minutes at 110^{o}C and was allowed to cool and weighed afterwards. The fat was extracted with petroleum ether for 2 – 3 hours without interruption by gentle heating. The ether (fat) was allowed to cool and extraction flask dismantled. The ether was evaporated on a water bath until no odour of ether remains. It was then cooled at a room temperature. The extraction flask and its extract were re-weighed and the weight recorded.

Calculations

(A + B) – A = B % ether extract = B/C x 100

Where A = flask weight, B = ether extract weight, C = sample weight

3.5.1.5 Determination of Percentage Crude Fibre Content of unfermented

Cassava Flour

The residue from ether extract was transferred into a digestion flask. 200 ml of the boiling H_2SO_4 solution and the anti-foaming agent were added and digestion flask was immediately connected with a condenser and then heated. At the end of 30 minutes, flask was removed, filled immediately through linen and washed with boiling water until washings are no longer acid. A quantity of NaOH solution was heated to a boiling point and was kept at this temperature under reflux condenser until used. The residue was washed back into flask with 200 ml of the boiling NaOH solution. Flask with reflux condenser was connected and was boiled for exactly 30 minutes.

The flask was removed at the end of 30 minutes and immediately filtered through the Gooch crucible. After thorough washing with boiling water, it was again washed with about 15 ml of 95% ethanol. Crucible and contents are dried at a constant weight at a temperature of 110^{o}C. It is then cooled in desiccators and weighed. Contents of crucible were incinerated in muffle furnace at 550^{o}C for 30 minutes until the carbonaceous matter was consumed. The content was weighed after it has been cooled in a desiccator. Record loss in weight as crude fibre.

Calculation

% crude fibre = $\frac{A-B \quad x\,100}{C}$ where, A = wt. of dry crucible and sample

B = wt. of incinerated crucible and ash, and C = sample weight.

3.5.1.6 Determination of percentage Crude Protein Content of unfermented

Triplicates 2.0 g of samples were weighed by the use of balance and then transferred into 500/650 ml digestion flask. A spoonful of $CuSO_4$- $NaSO_4$ mixture (acts as catalyst) and 15 ml -25 ml concentrated H_2SO_4 were added to the content in the digestion flask. Boiling chips were added and the sample digested till the sample becomes colourless. The digest was cooled and diluted with a small quantity of distilled ammonia- free water and then transferred in the distillation apparatus.

The Kjeldahl flask was rinsed with successive small quantities of water. A 100 ml conical flask containing 25 ml of boric acid solution with a few drops of mixed indicator was placed and 50 ml of 40% Sodium hydroxide solution to the test solution in the apparatus added. Ammonia was collected on boric acid after distilling and 100 ml to 150 ml of distillate was titrated against the standard acid until the first appearance of pink colour was observed. Run a reagent blank with equal volume of distilled water and titration volume was subtracted from that of sample titration volume.

Calculation

The N content of the sample can be calculated by the formula:

$$\text{Total Nitrogen } (N_T)\ (\text{g kg}^{-1}) = \frac{(\text{ml HCl} - \text{ml blank}) \times \text{Normality} \times 14.01}{\text{Weight of sample (g)} \times 10}$$

Therefore

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

3.5.2 Mineral Analysis

3.5.2.1 Determination of Calcium (Ca) Content of Flour (g/100g)

To determine the calcium nutrient, 5 ml concentrated acid and 5 ml of water were added to a weighed 2.0 g sample of flour. The sample was then run into micro wave oven for 2 hours for digestion. Sample was diluted to 50ml with deionised water. Calcium is analysed with atomic absorption spectrophotometer.

3.5.2.2 Determination of Iron (Fe) Content of Flour (mg/kg)

2.0 g of sample was weighed, while 5 ml concentrated acid and 5 ml of water were added to the sample. Then the sample was run in micro - wave oven for about 2 hours for digestion. Sample was diluted to 50 ml with deionised water. Iron is analysed with atomic absorption spectrophotometer.

3.5.2.3 Determination of Phosphorus (P) Content of Flour (g/100g)

2.0 g of sample was weighed, after 5 ml concentrated H_2SO_4 and 5 ml water was added to the sample. Then the sample was run in micro - wave oven for two hours. After digestion, the sample was diluted to 50ml with deionised water. Phosphorus was analysed with atomic absorption spectrophotometer.

3.5.3 Determination of pH, Total titratable acidity (TTA), Bulk density and Yield of Flour

3.5.3.1 Determination of pH

The pH meter (model, BA 350 EDT, Romania) instrument was standardised with standard buffer solution 4.0 and 7.0. 10 g of sample was weighed into 250 ml beaker and 20ml of distilled water added to obtain a slurry. The pH was then measured by inserting the electrodes into 10 ml of slurry in a beaker. The pH electrodes were allowed to stabilize before recording (Bainbridge *et al.*, 1996).

3.5.3.2 Determination of Total Titratable Acidity (TTA)

10 ml of flour slurry after determined the pH was transferred into 250 ml conical flask and 4 - 5 drops of phenolphthalein indicator was added and titrate against 25 ml 0.1M NaOH solution until the mixture turns pink. The titre volume was recorded and the percentage total titratable acidity (% TTA) as lactic acid was calculated by multiplying the titre volume by 0.09 (Bainbridge *et al.*,1996).

3.5.3.3 Determination of Bulk Density

2.0 g of the flour sample was weighed by a balance and then placed in a 10ml clean dry measuring cylinder. The sample was manually tapped for about 300 times and occupied volumes were determined. Bulk density was calculated as weight to volume ratio (Nwanekezi, 2009).

3.5.3.4 Determination of Flour Yield (%)

Approximately 10kg of unpeeled cassava roots was weighed by a balance. The roots were peeled and processed into unfermented cassava flour. After milling and sieving, the result was again weighed and the values recorded. The percentage flour yield was calculated as weight of the flour to the ratio of unpeeled cassava root multiplied by 100%.

Percentage flour yield is calculated as; Flour Yield/Unpeeled cassava root x 100 %.

3.6 DATA ANALYSIS

Data collected on all parameters studied were statistically analysed using analysis of Variance (ANOVA). Statistix (Version 9.1) statistical software was used in analysing the data. Differences between treatment means were determined using

Tukey HSD test at P = 0.01.

CHAPTER FOUR

4.0 RESULTS

4.1 PERCENTAGE PROXIMATE COMPOSITION OF UNFERMENTED CASSAVA FLOUR

Table 4.1: Effect of storage methods and storage days on percentage moisture content of unfermented cassava flour

Storage methods	Storage days			
	Day 0	**Day 7**	**Day 14**	**Means**
Woven polypropylene bag	11.00^{a*}	8.45^{b}	6.58^{c}	**8.68^{a}**
Trench	11.00^{a}	7.24^{bc}	6.93^{bc}	**8.39^{a}**
Wooden Box	11.00^{a}	8.45^{b}	7.17^{bc}	**8.87^{a}**
Plastic container	11.00^{a}	6.56^{c}	6.57^{c}	**8.04^{a}**
Means	**11.00^{a}**	**7.68^{b}**	**6.81^{b}**	
cv (%) 9.64				

*Means in columns carrying the same superscript letter are not significantly different at $p = 0.01$

Table 4.1 depicts the effect of storage methods and storage days on moisture content of unfermented cassava flour. The moisture content of the flour ranged from 6.56% to 11.00%. Plastic container method on Day 7 storage recorded the lowest moisture content of 6.56% whereas flour produced from fresh cassava root on storage Day 0 recorded the highest moisture content of 11.00%. Significant differences ($P< 0.01$) were observed in flour produced from fresh cassava root on Day 0 storage period among the two storage Days, 7 and 14 in all the storage methods. Also, plastic container method on Day 7 showed significantly lower moisture content of flour than both woven polypropylene bag and wooden box methods on storage Day 7 respectively.

Table 4.2: Effect of storage methods and storage days on percentage ash content of unfermented cassava flour

Storage methods	**Storage days**			
	Day 0	**Day 7**	**Day 14**	**Means**
Woven polypropylene bag	1.98^{ab*}	2.06^{ab}	1.97^{ab}	$\mathbf{2.00^{a}}$
Trench	1.98^{ab}	1.88^{ab}	2.04^{ab}	$\mathbf{1.97^{a}}$
Wooden Box	1.98^{ab}	1.94^{ab}	1.80^{ab}	$\mathbf{1.91^{a}}$
Plastic container	1.98^{ab}	1.07^{c}	2.14^{a}	$\mathbf{1.73^{a}}$
Means	$\mathbf{1.98^{a}}$	$\mathbf{1.74^{a}}$	$\mathbf{1.99^{a}}$	
cv (%)6.38				

*Means in columns carrying the same superscript letter are not significantly different at $p = 0.01$

The effect of storage methods and storage days on percentage ash content of unfermented cassava flour is presented in Table 4.2. The ash content of the flour ranged from 1.07% to 2.14%. Plastic container storage method on Day 7 storage period recorded the least ash content of 1.07% while plastic container method on Day 14 storage period recorded the highest ash content of 2.14%. Significant differences (P< 0.01), were observed in plastic container storage method on Day 7 storage period among all the storage methods and storage days.

Table 4.3: Effect of storage methods and storage days on percentage carbohydrate content of unfermented cassava flour

Storage methods	**Storage days**			
	Day 0	**Day 7**	**Day 14**	**Means**
Woven polypropylene bag	84.44^{a*}	82.85^{a}	80.60^{bc*}	**82.63^{a}**
Trench	84.44^{a}	82.61^{a}	80.60^{bc}	**82.55^{a}**
Wooden Box	84.44^{a}	83.63^{a}	80.60^{bc}	**82.89^{a}**
Plastic container	84.44^{a}	82.53^{ab}	80.54^{bc}	**82.50^{a}**
Means	**84.44^{a}**	**82.91^{a}**	**80.59^{b}**	
cv (%)1.05				

*Means in columns carrying the same superscript letter are not significantly different at *p* = 0.01

The effect of storage methods and storage days on percentage carbohydrate content of unfermented cassava flour is presented in Table 4.3.The carbohydrate content of the flour ranged from 80.54% to 84.44%. Plastic container storage method on Day 14 recorded the lowest carbohydrate content of 80.54% while flour from fresh cassava root on Day 0 recorded the highest carbohydrate content of 84.44%.Significant differences (P< 0.01) were observed between the flour produced from all the storage methods on storage Day 14 and flour produced from fresh cassava root on Day 0 storage period and the flour produced from all the storage methods on Day 7.

Table 4.4: Effect of storage methods and storage days on percentage fat content of unfermented cassava flour

Storage methods	Storage days			
	Day 0	**Day 7**	**Day 14**	**Means**
Woven polypropylene bag	3.20^{a*}	2.04^{b*}	2.01^{b}	**2.42^{a}**
Trench	3.20^{a}	2.49^{b}	1.39^{cd}	**2.36^{a}**
Wooden Box	3.20^{a}	2.51^{b}	0.97^{d}	**2.23^{a}**
Plastic container	3.20^{a}	2.51^{b}	1.50^{c}	**2.40^{a}**
Means	**3.20^{a}**	**2.39^{b}**	**1.47^{c}**	
cv (%)10.05				

*Means in columns carrying the same superscript letter are not significantly different at p = 0.01

Table 4.4 depicts the effect of storage methods and storage days on percentage fat content of unfermented cassava flour. The fat content of the flour ranged from 0.97 % to 3.20 %. Wooden box storage method on Day 14 recorded the lowest fat content of 0.97% while flour from fresh cassava root on Day 0 storage recorded the highest fat content of 3.20%. Significant differences ($P < 0.01$) were observed in flour produced from fresh cassava root on Day 0 storage period among storage Days, 7 and 14 in all storage methods. Again, wooden box method on storage Day 14 produced significantly lower fat content of flour then woven polypropylene bag and plastic container storage methods on storage Day 14 and all the storage methods on storage Day 7. Moreover, plastic container method on storage Day 14 also showed significantly lower fat content of flour than all storage methods on storage Day 7.

Table 4.5: Effect of storage methods and storage days on percentage fibre content of unfermented cassava flour

Storage methods	**Storage days**			
	Day 0	**Day 7**	**Day 14**	**Means**
Woven polypropylene bag	2.90^{b*}	3.35_{ab*}	3.81^{a*}	$\mathbf{3.35^{a}}$
Trench	2.90^{b}	3.41^{ab}	3.70^{a}	$\mathbf{3.35^{a}}$
Wooden Box	2.90^{b}	3.46^{ab}	3.67^{a}	$\mathbf{3.34^{a}}$
Plastic container	2.90^{b}	3.31^{ab}	3.88^{a}	$\mathbf{3.36^{a}}$
Means	$\mathbf{2.90^{b}}$	$\mathbf{3.40^{a}}$	$\mathbf{3.77^{a}}$	
cv (%)9.10				

*Means in columns carrying the same superscript letter are not significantly different at $p = 0.01$

Table 4.5 shows the effect of storage methods and storage days on fibre content of unfermented cassava flour. The fibre content of the flour ranged from 2.90% to 3.88%. Flour from fresh cassava root on Day 0 storage recorded the lowest fibre content of 2.90% whereas plastic container storage method on Day 14 storage periods recorded the highest fibre content of 3.88%.Statistically, significant differences (P< 0.01) were observed between the fibre content of the flour produced from all the storage methods on storage Day 14 and the flour produced from fresh cassava roots on storage Day 0.

Table 4.6: Effect of storage Methods and storage days on percentage protein content of unfermented cassava flour

Storage methods	Storage days			
	Day 0	**Day 7**	**Day 14**	**Means**
Woven polypropylene bag	3.00^{a*}	2.82^{a}	1.94^{b*}	**2.59^{a}**
Trench	3.00^{a}	2.77^{a}	2.10^{b}	**2.62^{a}**
Wooden Box	3.00^{a}	2.61^{a}	1.94^{b}	**2.52^{a}**
Plastic container	3.00^{a}	2.85^{a}	1.92^{b}	**2.59^{a}**
Means	**3.00^{a}**	**2.76^{a}**	**1.98^{b}**	
cv (%)7.12				

*Means in columns carrying the same superscript letter are not significantly different at p = 0.01

The effect of storage methods and storage days on percentage protein content of unfermented cassava flour is presented in Table 4.6. The protein content of the flour ranged from 1.92% to 3.00%. Plastic container storage method on Day 14 recorded the lowest protein content of 1.92% while flour produced from fresh cassava root on Day 0, storage recorded the highest protein content of 3.00%. Statistically, significant differences ($P<0.01$) were observed between storage Day 14 and storage Days 0 and 7 in all the storage methods.

Table 4.7: Effect of storage Methods on percentage proximate composition of unfermented cassava flour

Storage methods	Proximate composition					
	Moisture	**Ash**	**Carbohydrate**	**Fat**	**Fibre**	**Protein**

Woven polypropylene bag	7.11^{b}	2.00^{a*}	82.56^{ab}	2.20^{a}	3.54^{a}	2.58^{a}
Trench	7.52^{b}	1.97^{a}	82.27^{ab}	2.13^{ab}	3.49^{a}	2.62^{a}
Wooden Box	7.33^{b}	1.91^{a}	82.89^{a}	1.66^{b}	3.58^{a}	2.52^{a}
Plastic container	8.64^{a}	1.73^{a}	81.22^{b}	2.40^{a}	3.41^{a}	2.59^{a}
Means	**7.65^{b}**	**1.90^{a}**	**82.24^{a}**	**2.10^{ab}**	**3.51^{a}**	**2.58^{a}**

cv (%)13.94

*Means in columns carrying the same superscript letter are not significantly different at $p = 0.01$

The percentage proximate composition of unfermented cassava flour produced from the storage methods are presented in Table 4.7.

The flour from the woven polypropylene bag recorded the lowest moisture content of 7.11%, while plastic container recorded the highest moisture content of 8.64%. Significant differences ($P< 0.01$) were observed in the plastic container among the three storage methods.

The ash content of the flour ranged from 1.73% to 2.00%. Plastic container recorded the lowest ash content of 1.73% while woven polypropylene bag recorded the highest ash content of 2.00%. No Significant differences ($P> 0.01$), were observed among the storage methods.

The carbohydrate content of the flour ranged from 81.22% to 82.89%. Plastic container recorded the lowest mark of 81.22%, and wooden box recorded the highest carbohydrate content of 82.89%. Significant difference ($P< 0.01$) was observed between wooden box and plastic container storage method.

The flour produced from the wooden box storage recorded the least fat content of 1.66% with plastic container recorded the highest fat content of 2.40%. Significant differences ($P < 0.01$) were observed in the wooden box storage method among woven polypropylene bag and plastic container storage methods.

Lowest fibre content of 3.41% was recorded at the plastic container storage method, while the highest value of 3.58% was recorded in wooden box. However, significant difference ($P > 0.01$) was not observed among the treatment means statistically.

The protein content of the flour produced ranged from 2.52% to 2.62%. Wooden box recorded the lowest protein content of 2.52% while Trench recorded the highest protein content of 2.62%. However, no significant differences ($P > 0.01$) were observed with all the storage methods.

Table 4.8: Effect of storage days on percentage proximate composition of unfermented cassava flour

Storage days	**Proximate composition**					
	Moisture	**Ash**	**Carbohydrate**	**Fat**	**Fibre**	**Protein**
Day 0	8.45^{a}	1.74^{a*}	83.21^{a}	2.51^{a}	3.39^{a}	3.00^{a}
Day 7	7.94^{a}	1.89^{a}	82.90^{a}	2.31^{a}	3.46^{a}	2.76^{b}

Day 14	6.53^{b}	1.98^{a}	80.60^{b}	1.48^{b}	3.67^{a}	1.98^{c}
Means	**7.65^{a}**	**1.87^{a}**	**82.24^{a}**	**2.10^{a}**	**3.57^{a}**	**2.58^{a}**
cv (%) 13.94						

*Means in columns carrying the same superscript letter are not significantly different at p = 0.01

Table 4.8 reveals the effect of storage days on percentage proximate composition of unfermented cassava flour.

The moisture content of the flour ranged from 6.53% to 8.45%. Storage Day 14 recorded the lower moisture content of 6.53% whereas storage, Day 0 recorded the higher moisture content of 8.45%.Significant differences(P<0.01) were observed on storage Day 14 among the storage Days,0 and 7.

The ash content of the flour ranged from 1.74% to 1.98%. Storage Day 0 recorded the lowest ash content of 1.74 % whereas storage Day 14 recorded the highest ash content of 1.98%.NoSignificant differences (P> 0.01) were observed among the storage days.

The carbohydrate content of the flour ranged from 80.60% to 83.21%. Day 14 storage recorded the lower carbohydrate content of 80.60% while storage Day 0 recorded the higher carbohydrate content of 83.21%. Significant differences (P< 0.01) were observed between 14 days storage and the other two storage Days, 0 and 7.

The fat content of the flour ranged from 1.48% to 2.51%. Storage Day 14 recorded lower fat content of 1.48% whereas storage Day 0 recorded higher fat content of 2.51%. Significant difference (P< 0.01) was observed in storage Day 14 between the storage Days, 0 and 7.

The fibre content of the flour ranged from 3.39% to 3.67%.Lower fibre content of 3.39 % was recorded on Day 0 while higher fibre content of 3.67 % was recorded on Day 14 storage periods. However, no significant differences (P> 0.01) were observed within the storage days.

The protein content of the flour ranged from 1.98% to 3.00 %. Storage Day 14 recorded the lower protein content of 1.98 while higher protein content of 3.00% was recorded on storage Day 0. The effect of the three storage Days on protein content of the flour were significantly different (P< 0.01) from each other.

4.2: MINERAL COMPOSITION OF UNFERMENTED CASSAVA FLOUR

Table 4.9: Effect of storage methods and storage days on calcium (Ca) content of unfermented cassava flour (g/100g)

Storage methods	Storage days			
	Day 0	**Day 7**	**Day 14**	**Means**
Woven polypropylene bag	0.152^{ab*}	0.119^{b}	0.155^{ab}	**0.142^{ab}**
Trench	0.152^{ab}	0.136^{ab}	0.156^{ab}	**0.148^{ab}**

Wooden Box	0.152^{ab}	0.129^{ab}	0.144^{ab}	**0.142^{ab}**
Plastic container	0.152^{ab}	0.146^{ab}	0.165^{a}	**0.154^{ab}**
Means	**0.152^{ab}**	**0.133^{ab}**	**0.155^{ab}**	
c.v% 8.43				

*Means in columns carrying the same superscript letter are not significantly different at $p = 0.01$

Table 4.9 depicts the effect of storage methods and storage days on calcium content of unfermented cassava flour. The calcium content of the flour ranged from 0.119 g/100 g to 0.165 g/100 g. The lowest mark of 0.119 g/100 g was recorded in woven polypropylene bag storage method on Day 7. The highest calcium content of 0.165 g/100 g was recorded from plastic container storage method on Day 14 storage period. Statistically, significant differences (P<0.01) were observed between woven polypropylene bag storage method on storage Day 7 and plastic container storage methods on storage Day 14.

Table 4.10: Effect of storage methods and storage days on iron (Fe) content of unfermented cassava flour (mg/kg)

Storage methods	**Storage days**			
	Day 0	**Day 7**	**Day 14**	**Means**
Woven polypropylene bag	8.30^{d*}	8.33^{d}	9.35^{d}	**8.66^{b}**
Trench	8.30^{d}	3.72^{f}	14.69^{c}	**8.90^{b}**
Wooden Box	8.30^{d}	3.01^{f}	17.86^{b}	**9.72^{b}**
Plastic container	8.30^{d}	6.93^{e}	35.55^{a}	**16.93^{a}**
Means	**8.30^{b}**	**5.50^{c}**	**19.36^{a}**	
c.v% 3.41				

*Means in columns carrying the same superscript letter are not significantly different at $p = 0.01$

The effect of storage methods and storage days on Iron content of unfermented cassava flour is presented in Table 4.11. The iron (Fe) content of the flour ranged from 3.01 mg/kg to 35.55 mg/kg. Wooden box on Day 7 storage period recorded the lowest Iron content of 3.01 mg/kg while plastic container method on Day 14 storage period recorded the highest Iron content of 35.55 mg/kg. Significant differences ($P < 0.01$) were observed in all the storage methods on storage Day 0 among trench, wooden box and plastic container storage methods on storage Days, 7 and 14 respectively. Again, plastic container storage method on storage Day 14 showed significantly the highest iron (Fe) content of the flour than all the storage methods at the their respective storage days.

Table 4.11: Effect of storage methods and storage days on Phosphorus (P) content of unfermented cassava flour (g/100g)

Storage methods	**Storage days**			
	Day 0	**Day 7**	**Day 14**	**Means**
Woven polypropylene bag	0.164[a*]	0.199[a]	0.262[a]	**0.208[a]**
Trench	0.164[a]	0.167[a]	0.240[a]	**0.190[a]**
Wooden Box	0.164[a]	0.165[a]	0.199[a]	**0.176[a]**
Plastic container	0.164[a]	0.187[a]	0.232[a]	**0.194[a]**
Means	**0.164[a]**	**0.180[a]**	**0.233[a]**	

c.v% 14.25

*Means in columns carrying the same superscript letter are not significantly different at $p = 0.01$

Table 4.10 shows the effect of storage methods and storage days on phosphorus content of unfermented cassava flour produced. The phosphorus content of the flour ranged from 0.164 g/100 g to 0.262 g/100 g. The lowest phosphorus content of the flour was recorded from fresh cassava root on Day 0 whereas woven polypropylene bag on Day 14 recorded the highest phosphorus content of 0.262 g/100 g. However, there were no significant differences (P> 0.01) observed among the storage methods and storage days.

Table 4.12: Effect of storage methods on mineral composition of unfermented cassava flour

Storage methods	Mineral composition		
	Calcium (g/100g)	**Iron (mg/kg)**	**Phosphorus(g/100g)**
Woven polypropylene bag	0.14^{a*}	8.66^{b}	0.21^{a}
Trench	0.15^{a}	8.90^{b}	0.20^{a}
Wooden Box	0.14^{a}	9.72^{b}	0.19^{a}
Plastic container	0.15^{a}	16.92^{a}	0.21^{a}
Means	$\mathbf{0.145^{a}}$	$\mathbf{11.05^{a}}$	$\mathbf{0.20^{a}}$
c.v%	8.43	3.41	14.25

*Means in columns carrying the same superscript letter are not significantly different at p = 0.01

Table 4.12 represents the effects of storage methods on calcium, (g/100g), iron (mg/kg) and phosphorus (g/100g) contents of unfermented cassava flour.

The calcium (Ca) content of the flour ranged from 0.14 g/100 g to 0.15 g/100 g. The flour from the woven polypropylene bag and wooden box methods recorded the lowest calcium content 0.14 g/100 g with trench and plastic container storage methods recording the highest calcium content of 0.15 g/100 g. However, significant difference ($P > 0.01$) was not observed among the storage methods.

The Iron (Fe) content of the flour ranged from 8.66 mg/kg to 16.92 mg/kg. The flour from woven polypropylene bag method recorded the lowest iron content of 8.66 mg/kg with plastic container method recording the highest iron content of 16.92 mg/kg. Significant differences ($P < 0.01$) were observed in plastic container among the three storage methods.

The phosphorus (P) content of the flour ranged from 0.19 to 0.21(g/100g). The flour from wooden box recorded the lowest phosphorus content of 0.19 g/100 g whereas plastic container and woven polypropylene bag methods recorded the highest phosphorus content of 0.21g/100 g each. However, no significant differences ($P > 0.01$) were observed among the storage methods.

Table 4.13: Effect of storage days on mineral composition of unfermented cassava flour

Storage days	Mineral composition		
	Calcium (g/100g)	Iron (mg/kg)	Phosphorus (g/100g)
Day 0	0.152^{a*}	5.495^{b}	0.199^{a}
Day 7	0.146^{a}	8.300^{b}	0.179^{a}
Day 14	0.141^{a}	19.360^{a}	0.225^{a}
Means	$\mathbf{0.146^{a}}$	$\mathbf{11.052^{a}}$	$\mathbf{0.201^{a}}$

c.v%	8.43	3.41	14.25

*Means in columns carrying the same superscript letter are not significantly different at *p* = 0.01

Table 4.13 depicts the storage days on mineral composition of unfermented cassava flour

The calcium content of cassava flour ranged from 0.141g/100 g to 0.152 g/100 g. The lower calcium content was recorded on storage Day 14 as 0.141g/100 g and the higher recorded on Day 0 as 0.152 g/100 g. However, no significant differences ($P > 0.01$) were observed among the storage days.

The iron content of the flour produced ranged from 5.495 mg/kg to 19.360 mg/kg. Storage Day 0 recorded the lower Iron content of 5.495 mg/kg whereas storage Day 14 recorded the higher Iron content of 19.360 mg/kg. Significant difference ($P < 0.01$) was observed on storage Day 14 among the two storage Days, 0 and 7.

The flour from the storage Day 7 recorded the lowest phosphorus content of 0.179 g/100g and storage Day 14 recorded the highest value of 0.225 g/100g. Significant differences ($P < 0.01$) were observed between storage Days, 7 and 14.

4.3: TOTAL TITRATABLE ACIDITY (TTA), pH, BUIK DENSITY AND PERCENTAGE YIELD OF UNFERMENTED CASSAVA FLOUR

Table 4.14: Effect of storage methods and storage days on Total titratable acidity of unfermented cassava flour (%)

Storage methods	Storage days			
	Day 0	**Day 7**	**Day 14**	**Means**
Woven polypropylene bag	0.36^{d*}	0.83^{a}	0.58^{bc}	**0.59^{a}**
Trench	0.36^{d}	0.59^{bc}	0.55^{bcd}	**0.50^{a}**
Wooden Box	0.36^{d}	0.75^{ab}	0.58^{bc}	**0.56^{a}**
Plastic container	0.36^{d}	0.55^{bcd}	0.50^{cd}	**0.47^{a}**
Means	**0.36^{b}**	**0.68^{a}**	**0.55^{ab}**	
c.v% 11.02				

*Means in columns carrying the same superscript letter are not significantly different at $p = 0.01$

Table 4.14 shows the effect of storage methods and storage days on Total titratable acidity of cassava flour produced. The Total titratable acidity of the cassava flour ranged from 0.36% to 0.83%. The least Total titratable acidity of the flour was recorded from the fresh cassava root, on Day 0 as 0.36% whereas the highest total titratable acidity of the flour was recorded from woven polypropylene bag on storage Day 7 as 0.83%. Significant differences ($P < 0.01$) were observed in the flour produced from the fresh cassava roots on storage Day 0 among the woven polypropylene bag, trench and wooden box on storage Day 7 and both woven polypropylene bag and wooden box storage methods on storage Day 14.

Table 4.15: Effect of storage methods and storage days on pH of unfermented cassava flour

Storage methods	Storage days			
	Day 0	**Day 7**	**Day 14**	**Means**
Woven polypropylene bag	5.80^{a*}	5.37_{ab*}	5.19^{b}	**5.45^{a}**
Trench	5.80^{a}	5.66^{ab}	5.37^{ab}	**5.61^{a}**
Wooden Box	5.80^{a}	5.61^{ab}	5.60^{ab}	**5.67^{a}**
Plastic container	5.80^{a}	5.50^{ab}	5.33^{ab}	**5.54^{a}**

Means	**5.80^{a}**	**5.54^{a}**	**5.37^{a}**
c.v%2.69			

*Means in columns carrying the same superscript letter are not significantly different at *p* = 0.01

Table 4.15 depicts the effect of storage methods and storage days on pH of unfermented cassava flour. The pH of cassava flour ranged from 5.19 to 5.80. The least value of pH composition of the flour was recorded from woven polypropylene bag on Day 14 as 5.19 whereas flour produced from fresh cassava root, Day 0, recorded the highest pH value of 5.80. Significant differences (P< 0.01) were observed between the flour produced from fresh cassava root on storage Day 0 and woven polypropylene bags storage methods on storage Day 14.

Table 4.16: Effect of storage methods and storage days on Bulk density of cassava flour

Storage methods	**Storage days**			
	Day 0	**Day 7**	**Day 14**	**Means**
Woven polypropylene bag	0.51^{b*}	0.63^{a*}	0.63^{a}	**0. 59^{a}**
Trench	0.51^{b}	0.63^{a}	0.63^{a}	**0. 59^{a}**
Wooden Box	0.51^{b}	0.65^{a}	0.65^{a}	**0.60^{a}**
Plastic container	0.51^{b}	0.63^{a}	0.63^{a}	**0.59^{a}**
Means	**0.51^{b}**	**0.64^{a}**	**0.64^{a}**	
c.v% 1.38				

*Means in columns carrying the same superscript letter are not significantly different at *p* = 0.01

The Bulk density of the unfermented cassava flour produced from storage methods and storage days is presented in Table 4.16. The bulk density of the flour ranged from 0.51 to 0.65 g/cm^3. The lowest mark of the flour was recorded from fresh cassava root on Day 0, as 0.51 g/cm^3 whereas the highest mark of the flour was recorded from wooden box storage method on Days, 7 and 14 as 0.65 g/cm^3. Significant differences (P<0.01) were observed on storage Day 0 among storage Days, 7 and 14 in all the storage methods.

Table 4.17: Effect of storage methods and storage days on percentage yield of unfermented cassava flour

Storage methods	**Storage days**			
	Day 0	**Day 7**	**Day 14**	**Means**
Woven polypropylene bag	22.20^{a*}	17.63^{bcd}	16.63^{cd}	**18.32^{a}**
Trench	22.20^{a}	19.17^{b}	18.17^{bcd}	**19.88^{a}**
Wooden Box	22.20^{a}	18.53^{bc}	18.13^{bcd}	**19.62^{a}**
Plastic container	22.20^{a}	18.07^{bcd}	16.30^{d}	**18.86^{a}**
Means	**22.20^{a}**	**18.35^{b}**	**17.31^{b}**	
c.v% 3.19				

*Means in columns carrying the same superscript letter are not significantly different at *p* = 0.01

Table 4.17 reveals the effect of storage methods and storage days on percentage yield of unfermented cassava flour. The percentage yield of the flour ranged from 16.30 to 22.20. The flour from plastic container on Day 14 recorded the lowest percentage yield of 16.30 while the flour produced from the fresh cassava root on Day 0 recorded the highest percentage yield of 22.20. Significant differences (P< 0.01) were observed on Day 0 storage period among the two storage periods, 7 and

14 in all the storage methods. Also, plastic container storage method on storage Day 14 produced significantly the lower percentage yield than Trench and wooden box storage methods on storage Day 7 respectively.

Table 4.18: Effect of storage days on pH, Total titratable acidity, Bulk density and the percentage yield of unfermented cassava flour

Storage days	**Parameters**			
	pH	**Total titratable acidity (%)**	**Bulk density (g/cm^3)**	**% Yield**
Day 0	5.80^a	0.67^a	0.51^c	22.20^a
Day 7	5.54^b	0.57^b	0.64^a	18.35^c
Day 14	5.37^b	0.36^{bc}	0.63^a	17.31^d
Means	$\mathbf{5.57^a}$	$\mathbf{0.53^a}$	$\mathbf{0.59^a}$	$\mathbf{19.29^b}$
c.v%	2.69	11.02	1.38	3.19

Means in columns carrying the same superscript letter are not significantly different at $p = 0.01$

Table 4.18 represents the effects of storage days on pH, Total titratable acidity, Bulk density and percentage yield of unfermented cassava flour.

The pH of unfermented cassava flour ranged from 5.37 to 5.80. The flour on Day 14 recorded the lowest pH of 5.37 while the highest pH was recorded on storage Day 0 as 5.80. Significant differences ($P < 0.01$) were observed between storage Day 0 and other two storage Days, 7 and 14.

The Total titratable acidity of unfermented cassava flour ranged from 0.36% to 0.67%. The flour on Day 14 recorded the lowest value of 0.36% while the highest value of Total titratable acidity of 0.67% recorded on Day 0 storage. Significant differences ($P < 0.01$) were observed among the storage Day 0 and the other two storage Days, 7 and 14.

The bulk density of unfermented cassava flour ranged from 0.51 g/cm^3 to 0.64 g/cm^3. Storage Day 0 recorded the lowest value of flour as 0.51 g/cm^3 whereas the highest value of 0.64 g/cm^3 was recorded on Day 7 storage period. Significant differences ($P < 0.01$) were observed between storage Day 0 and storage Days, 7 and 14.

The percentage yield of unfermented cassava flour ranged from 17.31 to 22.20. The lowest value of the flour was recorded on Day 14 as 17.31% whereas flour produced from fresh cassava root (storage day 0) recorded the highest yield of 22.20%. Significant difference ($P < 0.01$) existed among all the storage days.

Table 4.19: Effect of storage methods on pH, Total titratable acidity, Bulk density and the percentage Yield of cassava flour

Storage methods	**Parameters**			
	pH	**Total titratable acidity (%)**	**Bulk density (g/cm^3)**	**% Yield**
Woven polypropylene bag	5.45^{a*}	0.59^{a}	0.59^{a}	18.82^{b}
Trench	5.61^{a}	0.50^{ab}	0.59^{a}	19.84^{a}
Wooden Box	5.67^{a}	0.57^{a}	0.60^{a}	19.62^{a}
Plastic container	5.54^{a}	0.47^{b}	0.59^{a}	18.86^{ab}
Means	5.57^{a}	0.53^{a}	0.59^{a}	19.29^{a}

c.v%	2.69	11.02	1.38	3.19

*Means in columns carrying the same superscript letter are not significantly different at $p = 0.01$

The pH of unfermented cassava flour ranged from 5.45 to 5.67. The lowest value of 5.45 was recorded at woven polypropylene bag and the highest value of 5.67 was recorded at wooden box storage method. However, no significant differences

($P > 0.01$) were observed among the storage methods.

The total titratable acidity of unfermented cassava flour produced ranged from 0.47% to 0.50%. The lowest value of 0.47% was recorded from plastic container storage method whereas woven polypropylene bag recorded the highest value of 0.59%. However, significant differences ($P < 0.01$) were observed between plastic container and the other two storage methods, woven polypropylene bag and wooden box.

The bulk density of unfermented cassava flour ranged between 0.59 g/cm^3 to 0.60 g/cm^3. Woven polypropylene bag, Trench, and Plastic container recorded lower bulk density of 0.59 g/cm^3 and the higher value was recorded from wooden box storage method as 0.60 g/cm^3. However, no significant differences ($P > 0.01$) were observed among the storage methods.

The percentage yield of unfermented cassava flour ranged from 18.82 to 19.84. The lowest percentage yield of flour was recorded from woven polypropylene bag as 18.82 whereas trench storage method recorded the highest value of percentage flour yield as 19.84. Significant differences ($P< 0.01$) were observed between woven polypropylene bag storage methods and storage methods, trench and wooden box.

CHAPTER FIVE

5.0 DISCUSSION

5.1PROXIMATE COMPOSITION OF UNFERMENTED CASSAVA FLOUR (%)

The results of moisture, ash, carbohydrate, fat, fibre and protein contents of unfermented cassava flour produced are presented in Tables 4.1, 4.2, 4.3, 4.4, 4.5 and 4.6 respectively.

5.1.1 Moisture Content (%)

The result revealed that moisture content of the flour ranged between 6.58% and 11.0% for both storage methods and storage periods. The highest moisture content of the flour was produced from fresh cassava roots as 11.00%. The least moisture content of the flour was recorded at plastic container storage method on storage Day 7 as 6.58%, which was significantly different from the flour produced from storage Day 0, woven polypropylene bag and wooden box storage methods on storage Day 7.The values obtained from the flour produced in all the storage methods and storage days are in consonance with the report of CSIR - FRI (2009). They are with the view that, high quality cassava flour (HQCF) must be within the moisture content range of 9.0% to 12.0%. The results also compare favourably with the report of Apea– Bah *et al.* (2011) of a moisture content range of 6.34% to
14.58%.

Also, Charles *et al.* (2005) and Shittu *et al.* (2005) worked on two cassava varieties, to produce high quality flour reported moisture range of 9.20% to 12.30% and 11.00% to 16.50% respectively. The moisture content of the flour decreased with increase in storage periods in all the storage methods except plastic container storage method on storage Days 7 and 14 .Significant differences (P< 0.01) existed in the moisture content of the flour produced in all the storage methods on storage Day 0 among all the storage methods on storage Days, 7 and 14. The reduction in moisture content of the flour may be due to respiration and transpiration of the cassava root. These are physiological activities that are promoted by high temperature and low relative humidity of the storage environment (Passam *et al.*, 2002).

Since moisture is an important parameter in storage of cassava flour, very high levels greater than 12% will allow for microbial growth and thus low levels are favourable and give relatively longer shelf - life. Though, all the flour samples had appreciable moisture levels, plastic container storage method on Day 7 storage period had the best moisture content hence has the potential for better shelf - life.

5.1.2 Ash Content (%)

The ash content gives a quantitative estimation of minerals available in a given food product (Eleazu *et al.*, 2012). Knowledge of the ash content in flours is essential because it allows the milling industries to estimate the expected flour yield as well as identifying functionality of flour (Park and Henneberry, 2010).The ash content of the cassava flour samples from the different storage methods and storage periods ranged from 1.07% to 2.14%. Significant differences (P> 0.01) did not exist in the ash content of the flour for storage methods and storage periods, except the plastic container storage method on Day 7 and on Day 14 storage periods. Values obtained were comparable to the range of 1% - 2.84% reported by Aryee, *et al.* (2006). The ash content recorded by plastic container storage method on Day 14 storage period as 2.14% was significantly higher than the ash content recorded by plastic container on storage Day 7 as 1.07% because as storage periods increased more mineral was generated. This gives an indication that there was high mineral component in the flour produced from the plastic container storage method on storage Day 14.

5.1.3 Carbohydrate Content (%)

The carbohydrate values of cassava flour ranged from 80.54% to 84.44% for storage methods and storage periods. The highest carbohydrate content was recorded as 84.44%from the flour produced from the fresh cassava root on Day 0 storage period while the least value was recorded as 80.54% from plastic container storage method on storage Day 14. Significant differences ($P < 0.01$) were observed between the carbohydrate content of the flour produced from the fresh cassava root on storage Day 0and the flour produced from all the storage methods on storage Day 14. These carbohydrates values obtained from cassava flour were consistent with the range of 80.00% to 90.00% as reported by Montagnac *et al.* (2009).

The carbohydrate contents of the flour produced decreased in all the storage methods as storage periods increase. However, the carbohydrate contents of the flour produced in all storage methods on storage Day 14 were significantly lower than the flour produced from the woven polypropylene bag, trench and wooden box storage methods on storage Day 7.These reductions may be attributed to the conversion of starch to sugar and respiratory losses of sugar as carbon dioxide.

Passam *et al.* (2002) reported that, respiration results in steady loss of carbohydrate in the form of carbon dioxide and water, while at the same time, respiratory loss of water occurs.

The carbohydrate values obtained in this study indicated that, cassava flour produced from all the storage methods with their holding periods are good, however, for reliable and energy security food as proposed by FAO (2008),flour produced from fresh cassava root on storage Day 0 and wooden box method on storage Day 7 are the most appropriate.

5.1.4 Fat Content (%)

All the cassava flour samples from storage methods and storage days had high fat content with the lowest being 0.97% for wooden box storage on Day 14 storage period. However, the values were still higher than those of0.1% to 0.4% and 0.65% reported by Charles *et al.,* (2005) and Padonou *et al.* (2005) respectively. Significant differences ($P< 0.01$) existed in the fat content of flour in all the storage methods on Day 0storage period amongst the studied storage methods and storage days.

The fat content of the flour produced from all the storage methods on storage Day 7 are significantly higher than the flour produced in trench, wooden box and plastic container storage methods on storage Day 14. Again, wooden box storage method on storage Day 14, which recorded the least value of fat content of the flour as 0.97%

was significantly lower than the value obtained from plastic container storage method on storage Day 14 as 1.50%.

The results obtained from this study indicated that, fat content of the flour decreased as storage periods increased. The decreasing trend did not abate on Day 7 storage period as it further decreased on Day 14 storage period in all the storage methods. This behaviour could be ascribed to the rising temperature in storage of cassava root (Rehman, 2006).Temperature is known to have an effect on physical characteristics of food fats. Weiss *et al.* (1983) has established that, as temperature increases, the solid fat index of certain foods decreases. Temperature could probably be the reason for the rate of decrease of crude fat of the flour produced. Besides, the decrease in fat might be attributed to the fact that, the micro-flora used fat in the cassava chips as a source of energy during drying duration (Onoja and Obizoba, 2009). On a whole, wooden box storage method on storage Day 14 produced good crude fat content of flour.

5.1.5 Fibre Content (%)

The crude fibre content of the cassava flour ranged between the minimum value of 2.90% to a maximum value of 3.88%. Although, these values were lower than the 4.00% reported by Gil and Buitrago (2002), the fibre content increased in all the storage methods as storage days increased. These increases could be associated with high moisture loss in storage of cassava roots due to high respiration as well as high transpiration activities (Ravi *et al.*, 2006).

Statistically, significant differences (P< 0.01) existed between the fibre content of the flour produced from all the storage methods on storage Day 14 and the flour produced from fresh cassava root on storage Day 0.Although, there were no significant differences between the fibre content of the flour produced in all the storage methods on storage Day 7 and the flour produced in all the methods on storage Day 14, however, plastic container storage method on storage Day 14 showed the best fibre content of the flour

5.1.6 Protein Content (%)

The crude protein content of the flour produced ranged from 1.92% to 3.00%.Plastic container storage method on Day 14 recorded the lowest value of cassava flour of 1.92% and the highest crude protein content of the flour was produced from fresh cassava root as 3.00%. Significant differences (P< 0.01) were observed between the flour produced on storage Day 14 and the other two storage Days, 0and 7 in all the storage methods. Values obtained were comparable to the range of 1.00% to 3.00% reported by Buitrago (2002). Although, the values obtained in this study were within range, however, protein content of the flour decreased as storage periods increased in all the storage methods. The decrease in the protein content may have been affected by tannins reported to form complexes with protein limiting their availability (Osunde and Orhevba, 2009).From these results, flour produced from fresh cassava root on storage Day 0 performed better as far as crude protein is concerned.

5.2 MINERAL COMPOSITION OF UNFERMENTEDCASSAVA FLOUR

The results of calcium, Iron and Phosphorus content of unfermented cassava flours are presented in Tables 4.9, 4.10 and 4.11respectively.

5.2.1 Calcium content (g/100g)

Calcium content of the flour produced from storage methods and storage periods ranged between 0.11 g/100g - 0.165 g/100g. Plastic container storage method on storage Day 14 recorded the highest calcium content of the flour as 0.165 g/100g, while the least value of 0.11 g/100g was recorded from woven polypropylene bag storage method on storage Day 7.Thecalcium content of the flour was in agreement with what was reported by Charles *et al.* (2005) for high quality cassava flour (136 to 369 mg/100g) except that of woven polypropylene bag method on storage Day 7. The Calcium content of the flour in this study reduced on storage Day 7 and then increased on storage Day 14 in all storage methods. Significant differences ($P< 0.01$) existed among woven polypropylene bag storage method on storage Day 7 and the rest of the methods with their corresponding storage periods. This low value of calcium content of flour produced from woven polypropylene bag method on storage Day 7 may be due to more ash used in physiological activities during storage of cassava roots. Comparatively, plastic container storage method on storage Day 14 is of method of choice as far as calcium content of the flour is concerned.

5.2.2 Iron Content (mg/kg)

The Iron content of the flours from the storage methods and storage days were within the ranged 3.01 mg/kg - 35.55 mg/kg. However, only plastic container storage method over the 14 days period recorded the highest value of 35.55 mg/kg which was within the acceptable range of 29 - 40 mg/100kg as reported by Charles *et al.*, (2005). There were significant differences (P< 0.01) in the iron content of the flours produced from trench, wooden box and plastic container storage methods on storage periods, 7 and 14 between the flour produced from fresh cassava root and woven polypropylene bag storage method on storage Days, 7 and 14. This increase in Iron content in all storage methods over 14 days storage period suggests that more ash was stored over 14 days storage periods. Again, plastic container storage method on storage Day 14 produced the best iron content of flour among the various storage methods with their respective storage days, hence could be included in the diets of both infants and adults respectively.

5.2.3 Phosphorus content (g/100g)

Phosphorus which was one of the major minerals identified had the phosphorus content of the flour ranging from 0.164 g/100g to 0.262 g/100g for storage methods and storage periods. The least value of 0.164 g/100g was recorded from flour produced from fresh cassava root and the highest value of 0.262 g/100g was recorded from woven polypropylene bag storage method on storage Day 14. There were no significant differences (P> 0.01) for storage methods as well as storage periods. Phosphorus content of the flour increased in all the storage methods as storage periods also increased. This increase in phosphorus content of the flour may be attributed to rapid starch synthesis (Akingbala *et al.*, 2005).

5.3 TOTAL TITRATABLE ACIDITY (TTA), pH, BULK DENSITY AND

PERCENTAGE YIELD OF UNFERMENTED CASSAVA FLOUR

The results of Total titratable acidity, pH, bulk density and percentage yield of unfermented cassava flours are presented in Tables 4.14, 4.15, 4.16, and 4.17 respectively.

5.3.1 Total Titratable Acidity

The results revealed that, TTA of the flour ranged between 0.36% and 0.83%. The TTA of the flour on Day 7 increased sharply and reached a plateau and then declined as the storage period progressed on Day 14.The values obtained were not in conformity with that obtained by the Council for Scientific and Industrial research – Food Research Institute's training manual, CSIR- FRI,2009 (<0.25 %). The quality of the unfermented cassava flour produced from this study may be affected slightly since their acidity was higher than the recommended flour. Significant differences ($P<0.01$) existed in the TTA of the flour produced from fresh cassava root on Day 0 storage period among woven polypropylene bag, trench and wooden box on storage Day 7 and woven polypropylene bag and wooden box storage methods on storage Day 14. Flour produced from fresh cassava root had the least value which was significantly lower than the value of the flour produced from woven polypropylene bag storage method on storage Day 7, may be due to strong dissociation of organic acids mainly lactic and formic acids involved (Akinrele, 2006).

5.3.2 pH

The pH of the flour produced from the storage methods and storage days ranged between 5.19to 5.80. The pH value of the flour produced was lower than what was reported by CSIR-FRI (2009) for high quality cassava flour (6-7). This reduction may be attributed to the hydrolysis of starch to sugar (Akingbala *et al.*, 2005).Significant differences ($P<0.01$) were observed between the flour produced from fresh cassava root on storage Day 0 and woven polypropylene bag storage method on storage Day 14.Statistically, no differences were observed between all the storage methods on storage Days, 7 and 14, pH content of the flour however, decreased in these methods with their respective storage days.

5.3.3 Bulk Density (g/cm^3)

The bulk density of the flour from both storage methods and storage days ranged from 0.51 to 0.65 g/cm^3. Bulk density in this context measures the degree of heaviness of flour (Adejuyitan *et al.*, 2009). According to Shittu *et al.* (2005), bulk density is a parameter that plays a significant role in determining the suitability of the flours for ease packaging and transportation of food particles. The bulk density of the flour produced was similar to what was reported by Hsu *et al.* (2003) with a bulk density of yam flour of 0.49 to 0.63 g/cm^3. It is also reported by Nelson – Quartey *et a.l* (2007) that flours with lower bulk density were more acceptable in preparation of diet for infants. It is therefore concluded that, flour produced on storage Day 0 with relatively low bulk density of 0.51 g/cm^3 could be more appropriate for food preparation. Significant differences ($P<0.01$) were observed between storage Day 0 and the two storage Days, 7and 14 in all the storage methods.

5.3.4 Flour Yield (%)

The percentage yield of unfermented cassava flour from fresh and stored cassava roots is presented in Table 4. 17. The percentage yield of the flour from storage methods and storage days ranged from 16.30 to 22.20. The percentage yield apparently reduced significantly (P<0.01) with increase in storage periods. The least value of 16.30 % was obtained as the flour yield for the roots stored in plastic container on Day 14 storage period, whereas 17.63% was obtained as the flour yield for the cassava roots stored in woven polypropylene bag on Day 7 storage period. However, the yield of unfermented cassava flour from fresh cassava roots was 22.20%.This was in agreement with the report of Gil and Buitrago (2002) that, for maximum economic value, the recovery rate of the flour should not be less than 18.00%. Therefore, woven polypropylene bag on storage periods, 7 and 14 and plastic container on Day 14 could not support cassava roots meant for production of unfermented cassava flour. The reduction of yield of cassava flour in all the storage methods as the storage periods increase could be ascribed to losses due to increasing difficulty of peeling, greater loss of pulp as peel and greater loss as fibre, which was removed during sieving(Akingbala *et al*., 2005). It could therefore be deduced from this study that, cassava roots suitable for unfermented cassava flour production can be stored in both Trench and Wooden box methods on Days, 7and 14 storage periods, whereas Plastic container on Day 7 could fairly support cassava roots meant for unfermented cassava flour.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

The main aim of this study was to determine the effect of different traditional storage methods and periods of cassava root on the yield and nutritional composition of unfermented flour.

The findings of the study included the following:

The results of this study revealed a varied impact of storage methods on the yield and nutritional composition of unfermented cassava flour over the storage periods. Storage Day 0 showed significantly the best flour yield, however, the root stored in trench containing moist wood-shaving on storage Days, 7 and 14 and wooden box container method on storage Days, 7 and 14 including plastic container method on storage Day 7 also showed appreciable levels of flour yield. Farmers and processors using these storage methods would not have to be apprehensive about storage conditions and therefore could adopt these methods.

In relation with proximate composition of unfermented cassava flour, plastic container storage method on storage Day 7 showed significantly the least moisture content of 6.56%. This implied that, it corresponds to lower microbial growth and hence longer shelf-life stability and better quality attributes. As far as ash content of unfermented flour was concerned, plastic container method on storage Day 14 is the method of choice. The study also revealed that storage Day 0 showed the best carbohydrate and protein contents of unfermented cassava flour as 84.44% and 3.00% respectively affected the flour produced positively. According to this study, flour produced from wooden box method on storage Day 14 alone is the method of choice as fat content was concerned. Plastic container method on storage Day 14 in general proved to produce flour with high fibre content thus could be considered the best method.

With regards to mineral composition, plastic container method on storage Day 14 showed significantly the higher calcium content of flour than the flour produced from woven polypropylene bag on storage Day 7. This means that, plastic container method on storage Day 14 is the method of choice as far as calcium content of flour is concerned. Plastic container method on storage Day 14 once again proved to show significantly the highest iron content of flour over the three other methods with their corresponding holding periods and thus seen to be the best method based on this study. This study again revealed that woven polypropylene bag method on storage Day 14 showed the highest phosphorous content of unfermented flour and therefore considered the method of choice.

It could therefore be deduced from the results that emerged from this study that, for best results, in unfermented flour yield and nutrients, cassava root stored in plastic container methods on storage Day 7 could be the method of choice.

6.2 RECOMMENDATION

It is recommended that all the four traditional storage methods under evaluation had appreciable levels of nutrients and chemical composition of flour and can therefore be used as a part of nutritional balanced diet. For economic and commercial reasons, production of unfermented cassava flour could best be stored in trench or wooden box methods containing moist wood- shaving for a period up to 14 days and plastic container method for a maximum period of 7 days. Lastly, to achieve an excellent unfermented cassava flour yield and nutritional quality, healthy fresh cassava roots should be acquired and stored immediately after harvest.

6.3 AREAS OF FUTURE STUDIES

- Research should be conducted on identifying the sensory and other functional qualities for its suitability for industrial purpose.
- Further work should be conducted on the two storage methods; plastic container and woven polypropylene bag by using either moist sawdust or wood-shaving as a lining material to assess the percentage yield of the flour beyond seven (7) days storage period.
- Storage durations could be extended to 21 days to access the quality of the cassava flour.

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APPENDIX

Appendix 1: Factorial AOV Table for MOISTURE

Source	DF	SS	MS	F	P
Reps	2	0.4954	0.2477		
days	2	23.8821	11.9411	21.98	0.0000
Storage	3	12.5728	4.1909	7.71	1.0011
days*Storage	6	26.1983	4.3664	8.04	0.0001

Error	22	11.9517	0.5433
Total	35	75.1002	
Grand Mean	7.6478	CV 9.64	

Appendix 2: Factorial AOV Table for ASH

Source	DF	SS	MS	F	P
reps	2	0.09842	0.04921		
days	2	0.45931	0.22965	15.61	0.0001
Storage	3	0.39740	0.13247	9.00	0.0004
days*Storage	6	1.64485	0.27414	18.64	0.0000
Error	22	0.32364	0.01471		
Total	35	2.92362			
Grand Mean	1.9022	CV 6.38			

Appendix 3: Factorial AOV Table for CARBOHYDRATE

Source	DF	SS	MS	F	P
reps	2	0.8971	0.4485		
days	2	48.7877	24.3938	32.80	0.0000
Storage	3	14.0361	4.6787	6.29	0.0030
days*Storage	6	17.8074	2.9679	3.99	0.0075

Error	22	16.3641	0.7438
Total	35	97.8924	
Grand Mean	82.237	CV 1.05	

Appendix 4: Factorial AOV Table for FAT

Source	DF	SS	MS	F	P
reps	2	0.0677	0.03384		
days	2	7.1219	3.56095	79.92	0.0000
Storage	3	2.6923	0.89742	20.14	0.0000
days*Storage	6	3.8262	0.63770	14.31	0.0000
Error	22	0.9803	0.04456		
Total	35	14.6883			
Grand Mean	2.0997	CV10.05			

Appendix 5: Factorial AOV Table for FIBRE

Source	DF	SS	MS	F	P
reps	2	0.08649	0.04324		
days	2	0.49894	0.24947	2.45	0.1092
Storage	3	0.14588	0.04863	0.48	0.7008
days*Storage	6	1.60648	0.26775	2.63	0.0445
Error	22	2.23731	0.10170		
Total	35	4.57510			
Grand Mean	3.5053	CV 9.10			

Appendix 6: Factorial AOV Table for PROTEIN

Source	DF	SS	MS	F	P

reps	2	0.03977	0.01989		
days	2	6.91242	3.45621	102.51	0.0000
Storage	3	0.05326	0.01775	0.53	0.6687
days*Storage	6	0.11018	0.01836	0.54	0.7687
Error	22	0.74176	0.03372		
Total	35	7.85739			
Grand Mean	2.5794	CV 7.12			

Appendix 7: Analysis of Variance Table for CALCIUM

Source	DF	SS	MS	F	P
Storage	3	9.070E-04	3.023E-04	1.98	0.1434
days	2	6.744E-04	3.372E-04	2.21	0.1313
Storage*days	6	3.797E-03	6.328E-04	4.15	0.0053
Error	24	3.659E-03	1.524E-04		
Total	35	9.037E-03			
Grand Mean	0.1465	CV 8.43			

Appendix 8: Analysis of Variance Table for IRON

Source	DF	SS	MS	F	P
Storage	3	419.45	139.816	985.03	0.0000
days	2	1289.72	644.860	4543.13	0.0000
Storage*days	6	797.91	132.984	936.90	0.0000
Error	24	3.41	0.142		
Total	35	2510.48			
Grand Mean	11.052	CV 3.41			

Appendix9: Analysis of Variance Table for PHOSPHORUS

Source	DF	SS	MS	F	P
Storage	3	0.00241	8.046E-04	0.98	0.4174
days	2	0.01252	6.260E-03	7.65	0.0027
Storage*days	6	0.01601	2.668E-03	3.26	0.0173
Error	24	0.01965	8.186E-04		
Total	35	0.05059			
Grand Mean	0.2008	CV 14.25			

Appendix 10: Analysis of Variance Table for pH

Source	DF	SS	MS	F	P
Storage	3	0.23846	0.07949	3.54	0.0297
days	2	1.11096	0.55548	24.74	0.0000
Storage*days	6	0.17951	0.02992	1.33	0.2815
Error	24	0.53887	0.02245		
Total	35	2.06779			
Grand Mean	5.5706	CV 2.69			

Appendix 11: Analysis of Variance Table for TTA

Source	DF	SS	MS	F	P
Storage	3	0.08001	0.02667	7.77	0.0009
days	2	0.59937	0.29969	87.29	0.0000

Storage*days	6	0.11398	0.01900	5.53	0.0010
Error	24	0.08240	0.00343		
Total	35	0.87576			
Grand Mean	0.5319	CV 11.02			

Appendix 12: Analysis of Variance Table for BULK DENSITY

Source	DF	SS	MS	F	P
Storage	3	0.00090	0.00030	4.49	0.0123
days	2	0.12587	0.06294	944.04	0.0000
Storage*days	6	0.00046	0.00008	1.15	0.3634
Error	24	0.00160	0.0007		
Total	35	0.12883			
Grand Mean	0.5936	CV 1.38			

Appendix 13: Analysis of Variance Table for YIELD

Source	DF	SS	MS	F	P
Storage	3	7.427	2.4758	6.52	0.0022
days	2	159.344	79.6719	209.97	0.0000
Storage*days	6	5.125	0.8542	2.25	0.0727
Error	24	9.107	0.3794		
Total	35	181.003			
Grand Mean	19.286	CV 3.19			