# EFFECTS OF STORAGE ENVIRONMENTS AND TIME ON SHEA NUTS (*Vitellaria paradoxa* C.F.Gaertn) AS IT AFFECT QUALITY OF SHEA BUTTER IN YOLA, ADAMAWA STATE.

**BY**

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**(M.Tech./CP/07/0301)**

**A project report submitted to the Postgraduate School, Modibbo Adama University of Technology, Yola in partial fulfillment of the requirements for the award of the Degree of Master of Technology (M.Tech.) in Postharvest Physiology and Storage Technology.**

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## DECLARATION

I hereby declare that this project title "Effect of storage environments and time on shea(*Vitellaria paradoxa* C.F.Gaertn)nuts as it affect the quality of shea butter in Yola,Adamawa state"was written by me and it is a record of my own research work. It has not been presented before in any previous application for a higher degree. All references cited have been duly acknowledged.

_____ _____

Bukar Nuhu Date

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## APPROVAL

This thesis entitled "Effects of storage environments and time on shea(*Vitellaria paradoxa* C.F.Gaertn) nuts as it affect the quality of shea butter in Yola" by Bukar Nuhu meets the requirements governing the award of Master of Technology Degree in Post-harvest Physiology and Storage Technology of the Department of Crop Production and Horticulture,Modibbo Adama University of Technology, Yola, Adamawa State and is approved for its contribution to knowledge and literary presentation.

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## DEDICATION

This work is dedicated to my beloved wife Mrs. Hauwa Nuhu and my children for their love and care.

**ACKNOWLEDGEMENT**

I wish to express my gratitude to Almighty God for His guidance and protection throughout the period of my studies. My thanks go to my project supervisor, Dr. D.T. Gungula for taking his time to guide me to the success of this research work. I would like to thank my Head of Department, Dr. B.B. Jakusko and the entire staff of the Department for their invaluable inputs throughout the period of my research work. I also wish to thank Mr. B.Y. Bagirei of the Department of Food Science and Technology for his immense recommendations and suggestions. Special thanks should be given to my student colleagues who helped in many ways. Finally, words alone cannot express the thanks I owe to my beloved wife, Mrs. Hauwa Nuhu and my children, Daniel, Elijah, and Anna for their patience and support.

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**ABSTRACT**

An experiment was conducted from September, 2009 to June, 2010 at the Department of Crop Production and Horticulture,Modibbo Adama University of Technology, Yola to study the effects of storage environments and time on shea(*Vitellaria paradoxa* C.F.Gaertn)nuts as it affect the quality of shea butter in Yola. A Factorial in Randomized Complete Block Design was used consisting of two factors-storage time and storage environments. The first factor (storage time) consisted of seven levels (storage for 0, 1.5, 3.0, 4.5, 6.0, 7.5 and 9 months), while the second factor (storage environments) consisted of two levels (open space and laboratory under ambient condition). The experiment, therefore, consisted of 2x7 treatment combinations and was replicated three times. The physico-chemical parameters and fatty acid composition determined were oil yield, oil density, refractive index, specific gravity, iodine value, saponification value, unsaponifiable matter, free fatty acid, stearic acid, oleic acid, linoleic acid, linolenic acid and palmitic acid. The results showed that storage time significantly ($P<0.01$) affected oil density, refractive index, specific gravity, saponification value, unsaponifiable matter, free fatty acid, stearic acid, linoleic acid, oleic acid and palmitic acid. Storage environments significantly ($P<0.01$) affected refractive index, iodine value, saponification value, free fatty acid, stearic acid, oleic acid, linoleic acid and linolenic acid. The interaction between storage time and storage environments significantly ($p<0.01$) affected oil density, refractive index, specific gravity, iodine value, saponification value, unsaponifiable matter, free fatty acid, stearic acid, oleic acid, linoleic acid and palmitic acid. Based on the parameters measured, storage of nuts for 9 months was found to be promising in terms of oil yield, linoleic acid, linolenic acid, free fatty acids and the saponofiation value. On the other hand,laboratory storage environment happened to perform very well in terms of oil yield, oil density, free fatty acid, iodine value, linoleic acid and palmitic acid as compared to open space storage environment. It is therefore, concluded that storage for 9 months and laboratory storage environment were the best storage time and storage environment.\espectively.

# CHAPTER ONE

## 1.0 INTRODUCTION

Shea nuts are obtained from the fruits of shea tree (*Vitellaria paradoxa* C.F.Gaertn), which exists in the wild and grows in an uncultivated state in most parts of Africa (Olaniyan and Oje, 2007). The butter extracted from it (Rajeev, 2011) is highly appreciated for its multi-uses (Mohagir *et al.,* 2009). Many vernacular names are used for *Vitellaria*, which is a reflection of its extensive range of occurrence (Fobil, 2010).It grows wild in the African savannah, an area that comprises more than a dozen countries and is approximately the size of America(Maliga,2008).

Shea nuts are harvested primarily for their fat contents (Dei *et al*., 2008). Most of the shea nuts collected each year are processed into shea butter for home consumption and to meet local market demand (FAO, 2004). However, since the first half of the twentieth century there has also been an export market for shea nuts as a cheap raw material source of vegetable fat. Unprocessed shea nuts have been exported to Europe for decades, primarily for the manufacture of chocolate in Switzerland and the United Kingdom (Harsch, 2008).

Shea butter is becoming more popular because of its unsaturated fatty acid composition as well as the potential utility of its unsaponifiable fraction now being used in cosmeceutical, pharmaceutical and nutraceutical applications (Moharram *et al*., 2006). As pointed out by Agbanga Karite (2010), traditionally, shea butter is used as a decongestant, an anti-inflammatory for sprains and arthritis, a healing salve for babies' umbilical cords, a lotion for hair and skin care, as cooking oil, and for lamp fuel. However, the protective and emollient properties of shea butter are most valued for skin

care. Sugri *et al.* (2010) also pointed out that it is possible to prolong the shelf life of plantains by using food –grade waxes such as shea butter by brushing on fruit surfaces.

Shea nuts are normally sundried for few days after they have been de-pulped from the shea fruits in order to bring the moisture contents to about 7% before storage or oil extraction (Fobil, 2010). The traditional open –to-sun drying method (aided by harmattan winds during the drying season in sub- Saharan West Africa) has several limitations which include, slow rate of drying (especially for harvests within the rainy season when cloud cover and unpredictable rains would cause drying to slow down); contamination (dirt, sand) and large microbial infestation; space limitation (as regards the total quantity that can be dried within a given time); loss and /or damage by rodents, birds and insects (Ododo and Igwe, 1999).

According to Kordylas (1990), dried kernels of shea have to be kept with care in a well ventilated area, in a loosely woven basket that allows air to circulate. They are turned regularly to prevent fermentation and to make sure they keep dry; otherwise the fat may go rancid. Careless storage reduces the percentage of oil obtained, and the fat breaks down and decomposes –changes which reduce the value of kernels.

It is important to note that quality plays a vital role in the marketing of any agricultural produce; and even for household consumption. The higher the quality of a produce, the more people go for it, and vice versa. Ferris *et al*. (2001) pointed out that, for the export market of shea butter, individual buyers specify their own quality conditions for purchase. The current market prefers the following kernel quality: FFA < 6%, kernel fat content 45-55%, water content < 7% and impurities < 1%. The preferred demand for butter quality for the cosmetic industry, however, varies depending on end

use, although there are some preferences, like non solvent extraction, natural sources (organic certification is possible), low FFA, clean white or yellow color (not grey), filtered to remove impurities, low water content, low odour, low melting point, and high unsaponifiable fraction (the portion with therapeutic properties, 3-12% of total extract) (Addaquay, 2004).

Manufacturers in the chocolate and other food industries prefer to buy the shea nuts as opposed to the butter so that they can have as much control as possible over the processing and quality of the final product. Nuts are also preferred because they can be stored for up to five years in the right conditions, while the butter is more expensive to store and deteriorates more rapidly (Fintrac, 1999; FAO, 2001).

As pointed out by FAO (2004), the value of shea butter depends very much on the market on which it is sold. It is, however, pitiful today, that most of the developing countries do not meet the international standard as regards to marketing of agricultural products. This is mostly as a result of low quality products, which is in line with poor storage techniques. A better solution needs to be sought for, in order to meet the international standard for marketing of agricultural products.

The objectives of this research, therefore, were to determine the:

i. Effects of storage environments of shea nuts on the quality of shea butter.
ii. Effects of storage time of shea nuts before oil extraction on the quality of shea butter.

# CHAPTER TWO

## 2.0 LITERATURE REVIEW

### 2.1 Origin and Distribution

The nomenclature, history and synonymy of the shea tree followed a very tortuous evolution since the oldest specimen was first collected by Mungo Park on May 26, 1797 before eventually arriving at the name *Vitellaria* with subspecies *paradoxa* and *nilotica* (Fobil, 2010). According to Agribusiness in Sustainable Natural Plant Products (ASNAPP) (2001), shea butter was not known in Europe before the seventeenth century. The tree has been called the 'God send' to the people of Africa. Found in the African Savannah, the tree is long-lived, fruiting only once a year, and developing the 'Karite' nut.

According to Pennington (1991) as cited by Olukemi *et al*. (2005), the shea tree is the only Sapotacea on the dry soils of the African Savannah. The fruit, similar to a small avocado, with a tasteful pulp contains a nut which kernel yields the precious butter by crushing. The shea nut grows naturally in the wild in the dry Savannah belt of West Africa from Senegal in the West to Sudan in the East, and onto the foothills of the Ethiopian highlands. It occurs in 19 countries across the African continent, namely Benin, Ghana, Chad, Burkina Faso, Cameroon, Central African Republic, Ethiopia, Guinea Bissau, Cote D'Ivoire, Mali, Niger, Nigeria, Senegal, Sierra Leone, Sudan, Togo, Uganda, Zaire and Guinea. (Fobil, 2010).

## 2.2 Sheanuts Production

Ferris *et al*. (2001) reported that Food and Agricultural Organization (FAO) estimated that Africa produces about 1,760, 000 MT of raw shea nuts annually from its wild trees mainly in the Savannah and Sahel regions. From this potential yield, only 35% of the nuts are gathered and 85% of this harvest is locally processed, to make 100, 000 MT of local butter. The remaining portions, approximately 65, 000 MT are exported, mostly to the food industry. Less than 5% of the exported butter is used in the international cosmetics and industry; a rough estimate would be 3000 MT per annum.Seven West African Countries (Ghana, Burkina Faso, Benin, Cote D'Ivoire, Nigeria, Mali and Togo) produce a total of about 500, 000 T of shea nuts. These countries export an estimated 270, 000T as raw nuts and convert the remaining 230, 000T into roughly 60,000T of crude shea butter, half of which is later exported (Addaquay, 2004).

## 2.3 Importance of Shea Butter

Shea butter is naturally rich in vitamins A, E and F, as well as number of other vitamins and minerals. Vitamins A and E help to soothe, hydrate, and balance the skin. They also provide skin collagen which assists with wrinkles and other signs of ageing. Vitamin F contains essential fatty acids, and helps protect and revitalize damaged skin and hair. Shea butter is an intense moisturizer for dry skin, and is a wonderful product for revitalizing dull or dry skin on the body or scalp. It promotes skin renewal, increases the circulation, and accelerates wound healing (Botanical, 2010).

Fobil (2010) has outlined the importance of shea nuts as follows: the shea nut serves as the main source of livelihood for the rural women and children who are

engaged in its gathering. The oil extracted from the nuts has antimicrobial properties, which gives it a place in herbal medicine. It is also used in the pharmaceutical and cosmetic industries as an important raw material and/or a precursor for the manufacture of soaps, candles, and cosmetics. Shea butter is used as a sedative or anodyne for the treatment of sprains, dislocations and the relief of minor aches and pains. Other important uses, as a pan- releasing agent in bread baking and as lubricant for donkey carts. Its by products, the brown solid that is left after extracting the oil and the hard protective shell, are used as a waterproofing material on the walls of mud buildings to protect them from the eroding forces of the wind and rain. Shea butter is used in cooking and as a flavoring in traditional dishes (Ihekoronye, 1999). Traditionally, it is also used to treat horses internally and externally for girth galls and other sores ( Fobil, 2010). Fobil (2010) also stated that shea butter is used as "white oil" to anoint the dead in Niger and is placed in traditional ritual shrines.

Alander and Andersson (2002) and Alander (2004) as cited by FAO (2004) identified other specific compounds such as triterpene alcohols, known to reduce inflammation; cinnamic acid esters, which have limited capacity to absorb ultraviolet (UV) radiation; and lupeol, which prevents the effects of skin ageing by inhibiting enzymes that degrade skin proteins. Shea butter also protects skin by stimulating production of structural proteins by specialized skin cells.FAO(2004) also stated that shea unsaponifiable is currently being used to produce an anti-inflammatory treatment for arthritis and a topical treatment for eczema and other skin conditions including herpes lesions.

## 2.4 Shea Butter Extraction

There are different methods used for the extraction of shea butter. The three most common methods used for extraction are described below:

### 2.4.1 Traditional method of shea butter processing

As pointed out by Woman by Nature (2011), after gathering as many fallen shea nuts, the hard pits are removed from the shea fruits and are steamed or boiled. This allows the seeds to separate from the shell for easy extraction. After boiling, the shea nuts are cracked and seeds left to dry in the sun for as long as it takes to completely dry them out. Once dry, the seeds are crushed using a mortar. The next st is to grill the seeds, further removing all traces of water. Then the roasted seeds are ground into a fine powder. The powder is then mixed with warm water and kneaded by hand, until the white, fatty butter starts to appear. The butter is then scooped out and put into a pot over a low heat. This allows it to liquefy, and any shell remnants to be removed. After the shea oil has been filtered, it is poured into a clean bowl to cool. As it cools, it is stirred carefully and consistently to form the final pure shea butter.

### 2.4.2 Mechanical extraction of shea butter .

Another way to produce shea butter is through mechanical extraction. This method uses machines to crack, grind and press the oil from the shea nut. This method, as well as using a clay filter to separate shea butter is still considered natural. It usually produces a butter that has the same look, smell and properties as using water extraction (Woman by Nature, 2011).

### 2.4.3 Chemical extraction of shea butter

According to Alaffia (2011), the most common method for producing oils is through hexane extraction. This is especially true in the industrialized nations; its use is uncommon in the 'less developed' nations. Jacobs (1999), fully described the use of Soxhlets apparatus for the extraction of substance like shea butter from shea nuts.

The advantage of the solvent process is the percentage of fatty acids extracted is maximized. The use of shea butter in the chocolate industry has standardized on this chemical method (Shea Butter Store, 2011).

## 2.5 Shea Butter Composition

According to Botanical (2010), the shea butter is composed of the following: colour — grey/off-white; odour — nutty with a pleasant aroma; free fatty acids, 0.17%; peroxide value, 4.8; non-saponifiables, < 6%; saponification value , 184; iodine value, 63; total saturated, 39 — 60; total monounsaturated, 40 — 48; total polyunsaturated, 4 — 10; melting point,89 — 95°C; oleic, 47.5%; palmitic, 3 — 9%; linoleic, 2 — 9%; stearic, 38%.

Ferris *et al.* (2001) also gave the chemical composition of the nut across Africa (Uganda, Nigeria, Burkina Faso and Mali). Table 1 shows the fatty acid profiles of shea butter for the four different countries.The seed kernels contain about 50% of a fat consisting mainly of stearic (36 — 47%) and oleic (33 — 50%) acids. The unsaponifiable fraction (2 — 11%) is composed of phenols: tocopherols,triterpenes(α,amyrin,lupeol, butyrospermol,parkeol), steroids(campesterol, stigmasterol, β, sitosterol, spinasterol,

Table 1: Chemical composition of shea nut across Africa

| | Lauric (12:0) | Myristic (14:0) | palmitic (16:0) | stearic (18:0) | oleic (18:1) | linoleic (18:2) | linolenic (18:3) |
|---|---|---|---|---|---|---|---|
| Literature | 0-0.5 | 0-1.6 | 39 | 30-50 | 41-50 | 4-11 | 0-7.5 |
| Uganda | | | 6.5 | 26.4 | 59.3 | 6.2 | 0.2 |
| Nigeria | | | 3.2 | 38.9 | 47.5 | 6.5 | 0.2 |
| Burkina Faso | | | 12.1 | 42.5 | 39.3 | 4.5 | 0.2 |
| Mali | | | 19 | 31.1 | 42.6 | 5.7 | 0.2 |

Source: Ferris *et al*. (2001)

delta-7-avenasterol) and the polyisoprenic hydrocarbon kariten (up to 2 %) (ASNAPP, 2001).

## 2.6 Quality Indices of Shea Butter

FAO (2004), stated that product quality of both shea nuts and shea butter depends primarily on post harvest processing, such as parboiling of shea nuts at the start of the season to prevent the seeds from germinating and to dry them more quickly. Sun drying of shea nut provides better quality than smoking nuts over a fire, which contaminates them with hydrocarbons. Free fatty acid (FFA) content offers a simply calculated index of quality, representing in effect the proportion lost to degradation. Through simple improvements in processing practices, it has been possible consistently to produce shea butter of commercially accepted grades, i.e. with FFA of less than 0.5 per cent.

As pointed out by American Shea Butter Institute (ASBI) (2010), the quality of shea butter may range from excellent to very poor. Shea butter of excellent quality may be used to treat a number of skin conditions, and serve as an excellent moisturizer as well. On the other hand, poor quality shea butter is good only for moisturizing purposes, and could be compared with products such as cocoa butter and mango butter.

High quality shea butter is associated with dark brown oil, which is the best indication that nuts have been correctly roasted before oil extraction. Such oil is more flavoursome and has a much longer shelf life (lighter coloured oils have been known to become rancid within two weeks, whereas dark brown oil can last for several months) (Ferris *et al*., 2001).

ASBI (2010) also pointed out that what sets shea butter apart from other seed oils is its exceptionally large healing fraction. The healing fraction contains important nutrients,vitamins,and other valuable phytonutrients required for healing. Depending on the source, the size of the healing fraction may range from 5% and upward. Some report the healing fraction as high as 17%. The larger the healing fraction the better the chances are for a good quality shea butter.

Fintrac (1999) reported that individual companies specify their own quality standards for purchases of shea nuts. The following is bench mark for the composition of the shea nut required for import: Free fatty acids (FFA) 6%, moisture content ≤ 7%, oil content ≥ 45%, latex, 4— 10%. The oil content is the most crucial element of the shea nut as that component is an important ingredient in the composition of the butter that goes into Cocoa Butter Equivalents (CBEs) and other by- products. If the oil content is higher and the FFA and moisture content is lower, then the exporter will receive a price premium. Shea butter buyers may also specify its iodine value and a melting point of between $30^{o}$c and 40 $^{o}$c - which signifies a minimum purity. Users in the cosmetic industry want a very highly refined butter product (such as the butter of Vitellaria *nilotica*) and may require a detailed specification of the different fatty acids, the refractive index and a saponification value.

**2.7 Effects of Storage Time on the Quality of Shea Nut**

The overall goal of storage in food security defined as the deliberate policy to guarantee the citizenry freedom from hunger, malnutrition and deprivation through actions that ensure adequate and consistent food supply at affordable prices. Agricultural

commodities are preserved in storage for the attainment of the following specific objectives: price stabilization, national and domestic food security, provision of raw materials for industry and international trade, provision for a country's strategic stock, enhancement of a nation's international status and provision of seed (Lale, 2002).

According to Ferris *et al*. (2001) traders buy shea nuts from villagers in the shea season (June, July, August), store for approximately six months and sell some of the nuts to towns folk and the majority back to villagers when the price has risen sufficiently to cover production costs and provide a healthy profits (usually in the period January to March).

As reported by Maranz *et al*. (2004), if kernels of shea are properly dried, they have a shelf life of five years or more. The age of the shea nuts can impact the solidity and consistency of the shea butter. Shea butter that is produced from nuts that are three months old or less will be much harder than shea butter produced from older nuts. Shea butter from nuts that have been stored at least one season is much softer and creamier than shea butter from non- aged nuts. The shea nuts from the previous season produce more oil and a creamier textured butter since they have lower moisture content. According to Squidoo (2011), the age of shea butter can affect the healing properties within shea butter. At moisture contents of about 7%, the kernel could be stored for up to two (2) years (Fobil, 2010).

### 2.8 Effects of Storage Environment on the Quality of Shea Nuts

The quality of the nuts, method of extraction and storage play a major role in determining the quality of shea butter (Rajeev, 2011).According to ASBI (2010), the

most significant factor responsible for variations in shea butter quality are the multitude of methods used to prepare shea butter (lack of a uniform procedure for preparation), and the environmental conditions the butter is exposed to after preparation.

When the fruits of shea are left for too long before picking, the seeds germinate and changes take place which alter their composition. They become unsuitable for the preparation of the shea butter and if used or mixed with good fruits, the quality of butter made is lowered. Nuts extracted from the fruits are normally dried. The dried kernels have to be kept with care in a well ventilated area, in a loosely woven basket that allows air to circulate. They are turned regularly to prevent fermentation and to make sure they keep dry; otherwise the fat may go rancid. Careless storage reduces the percentage oil obtained, and the fat breaks down and decomposes – changes which reduce the value of the kernels (Kordylas, 1990).

As pointed out by Ferris *et al*. (2001), drying the nuts requires some care and nuts are usually only dried for 2-3 hours per day. Slow drying prevents oil losses. If nuts are over dried or over heated they become black and either reduces the quality of the oil cannot be sold to processors. Heating the nuts also prevents the nuts from germination. Germination reduces oil quality and is associated with a bitter taste in the processed oil.

# CHAPTER THREE

## 3.0 MATERIALS AND METHOD

### 3.1 Experimental Site

The research work was carried out at the Crop Production and Horticulture Departmental Laboratory,Modibbo Adama University of Technology, Yola, Adamawa State.Yola is situated at $9^{0}16^{1}$N, $12^{0}35^{1}$E and is 152 m above sea level, with an average rainfall of 910.8mm (Adebayo and Tukur, 1999).

### 3.2 Sample Collection and Preparation

Physiologically matured shea butter fruits were harvested from the bush from August to September, 2009 for this research work. The fruits were de-pulped and kernels were dried for about 5 to 10 days before storage as described by Fobil (2010).

### 3.3 Shea Butter Extraction

For each treatment, the dry kernels were de-husked manually, by cracking them between two stones as described by Salunhe *et al.* (1992) cited by Fobil (2010). The nuts were then roasted, milled into powder before the oil extraction. Oil from the milled nuts were extracted with n-hexane solvent using Soxhlet apparatus as described by Pomeranz and Meloan (2004) and Jacobs (1999). The extraction was done at the Chemistry Departmental Laboratory, Modibbo Adama University of Technology, Yola.

### 3.4 Experimental Design and Layout

A Factorial in Randomized Complete Block Design (RCBD), was used; consisting of two factors:

Factor 1: Storage environment. This consisted of two storage environments which were open space where the nuts were exposed to the effects of weather elements like rainfall,wind etc. The other environment was the cool room environment where the nuts were kept in the laboratory with cross ventilation. In each of the storage environments, there were seven (7) treatments replicated three (3) times.

Factor 2: Storage time. Oil from some of the nuts were extracted and analyzed immediately after harvest and subsequently they were extracted and analyzed for the period of one and the half months interval for the period of nine months. This factor had seven (7) levels. Thus, the experiment consisted of 2 x 7 treatment combination and was replicated three (3) times.

### 3.5 Data Collection

#### 3.5.1 Physicochemical properties

Oil yield, density, specific gravity, refractive index, free fatty acids, iodine value, saponification value, unsaponifiable matter were determined as described below according to Onwuka (2005).

**3.5.1.1 Oil yield:** This was determined by taking the initial weight of the sample before oil extraction using electric weighing balance (Toledo mettler no. ab 204) and then taking

Environment 1 (open space) at ambient condition (25 $^{0}$c)

| Rep 1 | Rep 2 | Rep 3 |
|---|---|---|
| T1 | T2 | T5 |
| T2 | T3 | T6 |
| T3 | T4 | T1 |
| T4 | T5 | T7 |
| T5 | T6 | T2 |
| T6 | T7 | T4 |
| T7 | T1 | T3 |

Environment 2 (Laboratory).

| Rep 1 | Rep 2 | Rep 3 |
|---|---|---|
| T1 | T2 | T7 |
| T2 | T5 | T3 |
| T4 | T1 | T6 |
| T3 | T6 | T5 |
| T7 | T4 | T1 |
| T6 | T7 | T4 |
| T5 | T3 | T2 |

Figure 1: List of treatments and experimental layout.

Key: $T_1$ = Storage for 0 months

$T_2$ = Storage for 1.5 months

$T_3$ = Storage for 3 months

$T_4$ = Storage for 4.5 months

$T_5$ = Storage for 6 months

$T_6$ = Storage for 7.5 months

$T_7$ = Storage for 9 months

Rep = Replication

the weight of the oil for each sample after extraction. Oil yield was calculated as the quantity of oil extracted divided by the quantity of raw materials used, multiplied by 100.

$$\textit{Oil yield (\%)} = \frac{\textit{quantity of oil extracted (g)}}{\textit{Raw material used (g)}} \times \frac{100}{1}$$

**3.5.1.2 Specific gravity/density:** This was determined by thoroughly washing a 50 ml pycometer bottle with water, dried and weighed. The bottle was then filled with water and weighed. After drying the bottle, it was then filled with the oil sample and weighed. Specific gravity and density of the oil were then calculated as below:

$$\textit{Specific gravity} = \frac{\textit{Weight of x ml of oil}}{\textit{Weight of x ml of water}}$$

$$\textit{Density} = \frac{\textit{Weight of oil}}{\textit{Volume of oil}}$$

**3.5.1.3 Refractive index:** This was determined by using the Abbe's refractometer after it had been reset. The oil sample was smeared on the lower prism of the instrument and closed. Light was passed through the angle mirror. Using the fine adjustment, the telescope tubes were moved until the black shadow appeared central in the cross wire indicator, and then the refractive index was read.

**3.5.1.4 Free fatty acids:** 25 ml diethyl either was mixed with 25 ml alcohol and 1 ml phenolphthalein solution (1%) and these were carefully neutralized with 0.1 M NaOH.1-10 g of the melted fat was dissolved in the mixed neutral solvent and was titrated with aqueous 0. 1 M NaOH shaking constantly until a pink colour which persisted for 15 seconds was obtained. The FFA value was calculated thus,

$$FFA = \frac{\text{titre x molecular weight of oleic x 0.091}}{\text{Weight of oil}}$$

**3.5.1.5 Iodine value:** The oil was poured into a small beaker, and a small rod was added and a suitable quantity of the sample by difference was weighed into a dry glass stopper bottle of about 250 ml capacity.10 ml of carbon tetrachloride was added to the melted fat and dissolved.20 ml of wijis' solution was added and the stopper, previously moistened with potassium iodide solution was inserted and was allowed to stand in the dark for 30 minutes.15 ml of potassium iodide solution (10 %) and 100 ml water were added, mixed and titrated with 0.1 M thiosulphate solution using starch as indicator just before the end point (titration = a ml). a blank was carried out at the same time commencing with 10 ml of carbon tetrachloride (titration= b ml). The iodine value was computed thus,

$$Iodine\ value = \frac{(b-a)\ x1.269}{Wt\ (g)\ of\ sample}$$

**3.5.1.6 Saponification value:** 2 g of the butter was weighed into a conical flask and 25 ml of the alcoholic potassium hydroxide solution was added. A reflux condenser was attached and the flask was heated in boiling water for 1 hour, shaking frequently.1 ml of phenolphthalein (1 %) solution was added and was titrated hot the excess alkali with 0.5 M hydrochloric acid (titration = aml). A blank was also carried out at the same time (titration = b ml). The saponificattion value was therefore calculated as follows:

$$Saponification\ value = \frac{(b-a)\ x\ 28.05}{Wt\ (g)\ of\ sample}$$

**3.5.1.7 Unsaponifiable matter:** After the titration of the saponification value, the neutralized liquid alkaline was made with 1 ml of aqueous 3 M potassium hydroxide solution. It was then transferred to a separator and washed with water (50 ml less the volume of 0.5 M hydrochloric acid used). The solution was extracted while still warm 3 times with 50 ml quantities of diethyl ether. Each was poured into another separator containing 20 ml water. After the third extract had been added, the combined ether extracts was shaken with the first 20 ml of wash water and then vigorously with two further 20 ml quantities. The ether extract was washed twice with 20 ml of aqueous 0.5 M potassium hydroxide solution and at least twice with 20 ml quantity of water until the wash water was not longer alkaline to phenolphthalein. The ether extract was poured into a weighed flask, the solvent was evaporated. The residue was dried at 80 °C and was weighed to constant weight.

**3.5.2 Fatty acids profile:** Fatty acid profiles were assayed using High Performance Liquid Chromatograph (HPLC) (BLC — 10.254 nm flow cell), 15 cm c/8 column, by employing methanol — water (70:30v/v) solvent system (mobile phase). The amount of each fatty acid in the sample was expressed as percentage of the sum of all fatty acids in the sample as indicated below:

$$\% \text{ Fatty acid} = \left[ \frac{\text{Fatty acid peak area}}{\sum \text{Total fatty acid peak areas}} \right] x \quad 100$$

**3.6 Data analysis:** Data collected were subjected to analysis of variance (ANOVA) using Genstat statistical package. Means were separated using the Least Significant Difference (LSD) at 5% probability level.

# CHAPTER FOUR

## 4.0 RESULTS

### 4.1 Effects of the Treatments on the Physical Properties of Shea Butter

The mean values for the effects of storage time and environment on the physical properties of shea butter oil is presented in Table 2. The results revealed that there were highly significant differences ($P<0.01$) in storage time as regards to oil density, refractive index and specific gravity; no significant difference was observed in the oil yield ($P<0.05$).

For oil density, extracting the oil after the nuts had been stored for 3, 4.5, 6 and 7.5 months gave higher oil density. On the other hand, storage of the nuts for 0, 1.5, and 9 months before oil extraction gave low oil density.

In terms of refractive index, storage of nuts for 0, 4.5 and 6 months before oil extraction, gave the highest refractive index. However, storage of nuts for 1.5, 3, 7.5 and 9 months before oil extraction gave low refractive index.

As for specific gravity, storage of nuts for 0, 1.5, 3, 4.5 and 9 months before oil extraction had high specific gravity, while storage of nuts for 6, and 7.5 months had low specific gravity.

Significant differences were observed for storage environments ($P<0.05$) in terms of oil yield and specific gravity. Storage of nuts in the laboratory happened to have the highest mean in terms of oil yield and specific gravity in both cases. Highly significant difference was observed in terms of refractive index ($P<0.01$), with nuts stored in open space having the highest mean. No significant difference was observed for oil density ($P<0.05$).

Table 2: - Effect of treatments on the physical properties of shea butter

| Treatment<br>Storage time (months) | Oil yield (%) | Oil density ($g/cm^3$) | Refractive index | Specific gravity |
|---|---|---|---|---|
| 0 | 46.41 | 0.903 | 1.465 | 0.915 |
| 1.5 | 40.37 | 0.932 | 1.464 | 0.908 |
| 3.0 | 38.08 | 0.960 | 1.462 | 0.913 |
| 4.5 | 39.84 | 0.959 | 1.466 | 0.909 |
| 6.0 | 39.83 | 0.952 | 1.465 | 0.905 |
| 7.5 | 36.81 | 0.952 | 1.464 | 0.904 |
| 9.0 | 44.44 | 0.898 | 1.464 | 0.909 |
| SE | 4.25 | 0.00095 | 0.0004 | 0.0006 |
| LSD | 9.255 | 0.0019 | 0.0008 | 0.0013 |
| Prob. of F | 0.330 | <0.001 | <0.001 | <0.001 |
| Storage Environment | | | | |
| Open space | 39.41 | 0.936 | 1.465 | 0.909 |
| Laboratory | 42.24 | 0.937 | 1.464 | 0.909 |
| SE | 1.117 | 0.0005 | 0.0002 | 0.0003 |
| LSD | 2.397 | 0.0010 | 0.0004 | 0.0006 |
| Prob. of F | 0.024 | 0.434 | <0.001 | 0.015 |
| Interaction | | | | |
| SE | 4.734 | 0.0012 | 0.0005 | 0.0008 |
| LSD | 9.961 | 0.0021 | 0.0010 | 0.0016 |
| Prob. of F | 0.292 | <0.0001 | <0.001 | <0.001 |

Table 3 presents the means of the interaction between storage time and environment on the oil density, refractive index and specific gravity. Highly significant differences were observed ($P<0.01$) for the three parameters. The oil density was higher in the laboratory storage environment except at 4.5 and 6 months of storage that the oil density from nuts stored in open space environment was higher. Refractive index of the nuts stored in the laboratory was in all cases higher than the nuts stored in the open space except for storage for 3 months before oil extraction and for 7.5 months before oil extraction that open space storage gave higher and equal values respectively. Similarly, the interaction between storage time and storage environments reveals that extracting the oil after 1.5 and 3 months of storage gave higher specific gravity from nuts that were stored in the laboratory environment. As storage time increased beyond three months, nuts stored in open space gave higher specific gravity.

**4.2 Effects of the Treatments on the Chemical Properties of Shea Butter**

Table 4 presented the mean values for the effects of storage time and environment on the chemical properties of shea butter oil. The results showed that there were highly significant differences ($P<0.01$) in saponification value, unsaponifiable matter and free fatty acid.

For saponification value, storage of nuts for 0, 3, 4.5 and 7.5 months before oil extraction gave high saponification value. However, storage of nuts for 1.5, 6, and 9 months had low saponification value.

Table 3: - Interaction of storage time and environment on the oil density, refractive index and specific gravity of shea butter

| Storage time (months) | Density ($g/cm^3$) | | Refractive index | | Specific gravity | |
|---|---|---|---|---|---|---|
| | $E_1$ (open space) | $E_2$ (lab.) | $E_1$ (open space) | $E_2$ (lab.) | $E_1$ (open space) | $E_2$ (lab.) |
| 0 | 0.904 | 0.902 | 1.463 | 1.466 | 0.916 | 0.913 |
| 1.5 | 0.929 | 0.934 | 1.463 | 1.465 | 0.905 | 0.910 |
| 3.0 | 0.958 | 0.961 | 1.468 | 1.456 | 0.911 | 0.914 |
| 4.5 | 0.963 | 0.955 | 1.465 | 1.466 | 0.912 | 0.906 |
| 6.0 | 0.954 | 0.949 | 1.464 | 1.465 | 0.907 | 0.902 |
| 7.5 | 0.946 | 0.957 | 1.464 | 1.464 | 0.898 | 0.911 |
| 9.0 | 0.898 | 0.897 | 1.463 | 1.464 | 0.909 | 0.908 |

Storage of nuts for 3 months before oil extraction gave the highest mean in terms of unsaponifiable matter, followed closely by storage of nuts for 9,6,1.5 and 7.5 months before oil extraction. Storage of nuts for 0, and 4.5 months before oil extraction had low unsaponifiable matter.

For free fatty acid, storage of nuts for 3 months before oil extraction, gave the highest free fatty acid contents, followed by storage of nuts for 4.5 and 6 months. Storage for 0, 1.5, 7.5 and 9 months before oil extraction, gave low free fatty acid contents.

A significant difference was observed in terms of iodine value, where storage of nuts for 1.5,3,6 and 7.5 months before butter extraction, had high means, while storage for 0, 4.5 and 9 months gave low iodine value.

Highly significant differences existed for iodine value, saponification value and free fatty acids in terms of storage environments ($P<0.01$). Storage in laboratory had the highest mean with respect to iodine value and saponification value; it was the least in terms of free fatty acid. No significant effect was observed for unsaponifiable matter ($P<0.05$).

The means for the interaction between storage time and environment on the iodine value and saponification value of shea butter is presented in Table 5. Highly significant differences were observed ($P<0.01$) for the two parameters. For the interaction between storage time and storage environments of shea nuts, it shows that the iodine value was higher for the nuts stored in the laboratory than those that were stored in open space from the beginning of storage up to 9 months of storage. Extracting the oil after 3, 4.5,6 and 7.5 months of storage gave higher saponification value from nuts that were stored in

Table 4: - Effects of treatments on the chemical properties of shea butter

| Treatment<br>Storage time (months) | Iodine value ($I_2$g/100g) | Saponification value (mgKOH/g) | Unsaponifiable matter (%) | Free fatty acid (%) |
|---|---|---|---|---|
| 0 | 49.97 | 176.00 | 6.35 | 2.29 |
| 1.5 | 50.50 | 173.83 | 6.53 | 2.27 |
| 3.0 | 50.55 | 175.00 | 6.75 | 8.24 |
| 4.5 | 49.73 | 175.33 | 6.40 | 4.54 |
| 6.0 | 50.32 | 174.33 | 6.55 | 4.36 |
| 7.5 | 50.10 | 175.83 | 6.52 | 2.73 |
| 9.0 | 49.97 | 172.00 | 6.65 | 0.57 |
| SE | 0.199 | 0.333 | 0.0215 | 0.444 |
| LSD | 0.434 | 0.726 | 0.047 | 0.968 |
| Prob. of F | 0.012 | <0.001 | <0.001 | <0.001 |
| Storage Environment | | | | |
| Open space | 49.43 | 173.48 | 6.55 | 4.61 |
| Laboratory | 50.89 | 175.76 | 6.52 | 2.53 |
| SE | 0.087 | 0.172 | 0.024 | 0.16 |
| LSD | 0.187 | 0.368 | 0.052 | 0.343 |
| Prob. of F | <0.001 | <0.001 | 0.343 | <0.001 |
| Interaction | | | | |
| SE | 0.2574 | 0.4629 | 0.050 | 0.535 |
| LSD | 0.531 | 0.9521 | 0.105 | 1.112 |
| Prob. of F | <0.001 | <0.001 | <0.001 | <0.001 |

Table 5:- Interaction table for the effect of storage time and environment on the iodine value and saponification value of shea butter

| | Iodine value ($I_2$g/100g) | | Saponification value (mgKOH/g) | |
|---|---|---|---|---|
| Storage time (months) | $E_1$ (open space) | $E_2$ (lab.) | $E_1$ (open space) | $E_2$ (lab.) |
| 0 | 49.07 | 50.87 | 177.67 | 174.33 |
| 1.5 | 49.77 | 51.23 | 176.33 | 171.33 |
| 3.0 | 48.77 | 52.33 | 171.33 | 178.67 |
| 4.5 | 49.07 | 50.40 | 175.33 | 175.33 |
| 6.0 | 50.13 | 50.50 | 170.00 | 178.67 |
| 7.5 | 50.07 | 50.13 | 171.33 | 180.33 |
| 9.0 | 49.17 | 50.77 | 172.33 | 171.67 |

Table 6: - Interaction table for the effect of storage time and environment on the unsaponifiable matter and free fatty acid of shea butter

| | Unsaponifiable matter (%) | | Free fatty acid (%) | |
|---|---|---|---|---|
| Storage time (months) | $E_1$ (open space) | $E_2$ (lab.) | $E_1$ (open space) | $E_2$ (lab.) |
| 0 | 6.23 | 6.47 | 2.36 | 2.21 |
| 1.5 | 6.40 | 6.67 | 3.02 | 1.52 |
| 3.0 | 6.70 | 6.80 | 10.35 | 6.13 |
| 4.5 | 6.43 | 6.37 | 7.01 | 2.06 |
| 6.0 | 6.77 | 6.33 | 6.45 | 2.28 |
| 7.5 | 6.67 | 6.37 | 2.47 | 2.99 |
| 9.0 | 6.63 | 6.67 | 0.59 | 0.55 |

the laboratory, except for extracting the oil after storage for 0,1.5, and 9 months where open space storage gave higher values than laboratory storage.

Table 6 presents the interaction between storage time and environments on the unsaponifiable matter and free fatty acid. Results showed that there were highly significant differences ($P<0.01$) in both cases. For unsaponifiable matter, it clearly reveals that extracting the oil after 1.5 and 3 months of storage gave higher unsaponifiable matter contents from nuts that were stored in the laboratory. However, as storage time increased beyond 3 months, nuts stored in open space gave higher unsaponifiable matter up to 7.5 months of storage. Storage of nuts in the open space gave higher FFA than nuts stored in the laboratory from the beginning of the storage to the end of the storage (9 months) except for storage for 7.5 months where storage in the laboratory gave higher FFA value.

### 4.3 Effects of Treatments on the Fatty Acid Profiles of the Shea Butter

Table 7 presented the results for the effects of storage time and environment on the fatty acid composition. Storage time showed highly significant differences ($P<0.01$) on the stearic, oleic, linoleic and palmitic acid contents of the butter, and a significant difference ($P<0.05$) on the linolenic acid contents of the shea butter.

Storage of nuts for 4.5, 7.5 and 9 months before oil extraction had high stearic acid contents, while storage for 0, 1.5, 3, 6 months gave low stearic acid contents.

For oleic contents, storage for 6 and 7.5 months had the highest mean in terms of oleic contents, while storage for 0,1.5,3,4.5 and 9 months gave low oleic contents.

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Table 7: - Effects of treatments on the fatty acid profiles of shea butter

| Treatment<br>Storage time (months) | Stearic acid<br>(%) | Oleic acid<br>(%) | Linoleic acid<br>(%) | Linolenic acid<br>(%) | Palmitic acid<br>(%) |
|---|---|---|---|---|---|
| 0 | 27.28 | 49.57 | 5.22 | 0.40 | 6.32 |
| 1.5 | 27.35 | 49.77 | 4.88 | 0.30 | 6.08 |
| 3.0 | 27.62 | 48.95 | 5.10 | 0.25 | 6.12 |
| 4.5 | 29.05 | 49.57 | 4.57 | 0.35 | 6.03 |
| 6.0 | 27.55 | 50.25 | 4.82 | 0.35 | 6.07 |
| 7.5 | 28.38 | 50.18 | 5.15 | 0.40 | 6.30 |
| 9.0 | 28.07 | 49.55 | 5.25 | 0.40 | 6.13 |
| SE | 0.03 | 0.036 | 0.035 | 0.000 | 0.033 |
| LSD | 0.065 | 0.078 | 0.075 | 0.00 | 0.071 |
| Prob. of F | <0.001 | <0.001 | <0.001 | 0.02 | <0.001 |
| Storage Environment | | | | | |
| Open space | 27.81 | 49.77 | 4. 94 | 0.36 | 6.17 |
| Laboratory | 28.00 | 49.61 | 5.05 | 0.34 | 6.13 |
| SE | 0.02 | 0.021 | 0.016 | 0.00 | 0.02 |
| LSD | 0.043 | 0.046 | 0.034 | 0.000 | 0.043 |
| Prob. of F | <0.001 | <0.001 | <0.001 | 0.002 | 0.12 |
| Interaction | | | | | |
| SE | 0.048 | 0.054 | 0.045 | 0.000 | 0.0500 |
| LSD | 0.099 | 0.110 | 0.093 | 0.000 | 0.1028 |
| Prob. of F | <0.001 | <0.001 | <0.001 | 0.017 | 0.003 |

For linoleic acid storage for 0, 3, 7.5 and 9 months had the highest mean, while storage for 1.5, 4.5,6, and 9 months had the lowest means.

As for palmitic acid, storage for 0, 7.5 months gave the highest mean, followed by storage for 9 and 3 months. Storage for 1.5, 4.5, 6 months were the lowest.

Storage of nuts for 0, 7.5 and 9 months before oil extraction, gave the highest linolenic acid contents, followed by storage of nuts for 4.5 and 6 months. Storage of nuts for 1.5, 3 months were the lowest in terms of linolenic acid contents.

Highly significant differences were exhibited for storage environments in terms of stearic, oleic, linoleic, linolenic acid ($P<0.01$); a non significant difference was shown for palmitic acid ($P<0.05$). Storage in the laboratory had the highest mean in terms of stearic and linoleic acid contents; it was the lowest in terms of oleic and linolenic acid contents.

Table 8 presents the interaction between storage time and environment on the stearic and oleic acids composition of Shea butter. Highly significant differences were observed ($P<0.01$) for both parameters.

Extracting the oil after 3, 6 and 7.5 months of storage, gave higher stearic acid contents from nuts that were stored in open space. However, at 0, 1.5, 4.5 and 9 months of storage, nuts that were stored in the laboratory gave the higher stearic acid contents. Oleic acid composition was higher under open space storage for the first 4.5 months from the beginning of the storage of the nuts. As the storage time increases beyond 4.5 months, nuts stored in the laboratory gave higher oleic acid contents up to 9 months of storage.

The result of the interaction between storage time and environment on linoleic, linolenic and palmitic acid composition of shea butter is presented in Table 9.Highly

Table 8: - Interaction table for the effect of storage time and environment on the stearic and oleic acids of shea butter

| | Stearic acid (%) | | Oleic acid (%) | |
|---|---|---|---|---|
| Storage time (months) | $E_1$ (open space) | $E_2$ (lab.) | $E_1$ (open space) | $E_2$ (lab.) |
| 0 | 27.23 | 27.33 | 50.10 | 49.03 |
| 1.5 | 26.40 | 28.30 | 50.33 | 49.20 |
| 3.0 | 28.00 | 27.23 | 49.03 | 48.87 |
| 4.5 | 29.03 | 29.07 | 49.77 | 49.37 |
| 6.0 | 27.87 | 27.23 | 50.03 | 50.47 |
| 7.5 | 30.03 | 26.73 | 50.03 | 50.33 |
| 9.0 | 26.07 | 30.07 | 49.07 | 50.03 |

Table 9: - Interaction table for the effect of storage time and environment on the linoleic, linolenic and palmitic acids of shea butter

| | Linoleic acid (%) | | linolenic acid (%) | | Palmitic acid (%) | |
|---|---|---|---|---|---|---|
| Storage time | $E_1$ (open space) | $E_2$ (lab.) | $E_1$ (open space) | $E_2$ (lab.) | $E_1$ (open space) | $E_2$ (lab.) |
| 0 | 5.03 | 5.40 | 0.40 | 0.40 | 6.27 | 6.37 |
| 1.5 | 4.77 | 5.00 | 0.20 | 0.40 | 6.03 | 6.13 |
| 3.0 | 5.17 | 5.03 | 0.30 | 0.20 | 6.20 | 6.03 |
| 4.5 | 4.37 | 4.77 | 0.40 | 0.30 | 6.03 | 6.03 |
| 6.0 | 4.77 | 4.87 | 0.40 | 0.30 | 6.03 | 6.10 |
| 7.5 | 5.27 | 5.03 | 0.40 | 0.40 | 6.37 | 6.23 |
| 9.0 | 5.23 | 5.27 | 0.40 | 0.40 | 6.23 | 6.03 |

significant differences were observed ($P<0.01$) for linoleic and palmitic acid composition, except for linolenic acid, where a significant differences existed ($P<0.05$). The interaction reveals that the linoleic acid contents was higher at 0,1.5,4.5,6 and 9 months of storage in the laboratory, however, it was higher at 3 and 7.5 months of storage for nuts stored in open space. Similarly, the linolenic acid contents was higher under open space storage environment at 3, 4.5 and 6 months of storage of shea nuts except for 1.5 months storage where laboratory storage environment was higher. It was also noticed that extracting the oil after 7.5 and 9 months of storage gave higher palmitic acid contents from nuts that were stored in open space. However, laboratory storage environment gave higher values at 1.5 and 6 months of storage of shea nuts.

# CHAPTER FIVE

## 5.0 DISCUSSION

### 5.1 Physical Properties

With the emerging shea oil market in the world, its oil yield or fat content is the most important characteristics to be considered (Okullo *et al*., 2010). The significant difference observed in the experiment for the different storage environments, where shea nuts stored in the laboratory had the highest oil yield than those stored in open space, might be attributed to the harsh weather conditions shea nuts being stored in open space had been exposed to, such as high temperatures from the sun which aided in the lost of oil during the prolonged time of storage. Similar result was recorded by Ferris *et al.* (2001) that when shea nuts are over dried or over heated, oil is lost.

Ohlson (1983) as cited by Abramovic and Abram (2005) reported that density of oil increases as the degree of unsaturation increases. It was also noted by Abramovic and Abram (2005) that as storage temperature increases, the density of oil decreases. The differences observed for oil density as regards to storage time could be due to the variations in temperatures during the period of storage of the nuts. It may also be due to the differences in the degree of unsaturation of the nuts over time.

Differences in storage temperatures due to the different storage environments might have caused the difference observed in refractive index among the various storage time and environment. Cheronis *et al.* (1983) reported that the refractive index varies significantly with the temperature. The value of the refractive index decreases by 0.00035 to 0.00055 for each degree rise in temperature. According to Fashina and Ajibola (1989)

as cited by Olaniyan and Oje (2007), the refractive index is used for rapid sorting of fats and oils of suspected adulterations. Shea butter continues to be adulterated as heating temperature increased beyond 90 $^{o}$C.

The variations observed in the time of storage and storage environments for specific gravity, might be attributed to changes in heating temperature. Olaniyan and Oje (2007) have found out that specific gravity of shea butter oil decreases, with increase in heating temperature. This was because of the burning of the oil as the heating temperature increased and increase in volume due to expansion of the oil as a result of heating.

The positive interaction shown by the treatments on the oil density might be due to the changes in temperature in the two different storage environments, and also during the time of storage; as density of oil is inversely proportional to temperature.

The highly significant difference observed for the interaction as regard to refractive index might be attributed to increase in heating temperature during the process of oil extraction; as refractive index varies significantly with the temperature. In the same vein, the significant variation noticed for the interaction with regards to specific gravity could be associated with the expansion of the oil as a result of heating, which consequently affected the specific gravity of the butter.

**5.2 Chemical Properties**

The differences noticed in storage time and storage environment as regards to saponification value might be linked to temperature variations during extraction, which is

inversely proportional to the saponification value. The high saponification value noticed in the treatments indicates the presence of high percentage of fatty acids in the oil (Omolara and Dosumu, 009) as cited by Okoye *et al.* (2011). High saponification value may suggests possible use of the oil in the soap industry. Therefore, the higher the temperature of oil extraction, the lower the chance of the oil being used for manufacturing of soaps.

The highly significant variation that existed for storage time as regards to unsaponifiable matter (the healing fractions) could be attributed to the different sources the shea fruits were obtained which normally affects the level of the healing fractions. It could also be due to the age of the shea butter and the storage conditions of the product before analysis, which could have affected the healing properties within the shea butter. Similar information was given by Squidoo (2011).

The variations observed in storage time and environment in terms of free fatty acid contents could either be due to seasonal effect on kernels, or poor storage conditions at source after fat extraction due to oxidation (Dei *et al*., 2008). It may also be attributed to the recalcitrant nature of shea fruits; early germination may increase the free fatty acid of shea oil (Okullo *et al.,* 2010).

Iodine value measures the degree of unsaturation in vegetable oils (Onwuka, 2005). The variations observed for storage time and storage environment as it relates to iodine value might be due to differences in heating temperatures during oil extraction. Olaniyan and Oje (2007) mentioned that iodine value decreases with increase in heating temperatures of shea butter. It may also be due to the differences in the storage environments of the shea nuts as shade affects the iodine value (James, 1961).

The higher values obtained for the iodine values for the nuts stored in the laboratory than those that were stored in open space environment throughout the storage period, might be due to the difference in the storage environments of the shea nuts, as shade affect the iodine value. Temperature variations during storage of shea nuts might have caused the high variation in the saponification value obtained from the two environments.

The highly significant variations observed for the interaction between the storage time and environments on the unsaponifiable matter of the shea nuts could have been due to different sources the shea fruits were obtained or due to the storage conditions the nuts were stored which could have affected the healing properties within the shea butter. On the other hand, the highly significant variations that existed in the FFA of the nuts for the different environments during the storage period might be attributed to seasonal effect on kernels, such as rain fall or dew which affected the FFA level of the Shea nuts stored in open space. Low FFA may suggest its suitability as cooking oil.

### 5.3 Fatty Acid Profile

The differences observed for stearic acid contents with respect to storage time and storage environments might have been due to the genetic variability (Okullo *et al.*, 2010) among the nuts collected from different sources or it might be due to the differences in the storage environments; warm climates favor the formation of unsaturated acids (James, 1961).

Variations observed in terms of oleic acid contents with respect to the effects of storage time on the quality of shea butter may be due to the differences in time (age) of

storage of the nuts; shea nuts that have been stored for long, is softer in terms of butter than the one that have been stored for a short time. Similar records was given by Maranz *et al.* (2004) that shea butter that is produced from nuts that are three months old or less will be much harder than shea butter produced from older nuts. The difference observed in terms of storage environment might be attributed to high temperature in the open space environment where the nuts were stored, as warm climates favor the formation of unsaturated acids.

The differences observed in relation to storage time and storage environment with respect to linoleic acid contents may be due to genetic variability among the shea nuts.

Differences that existed among the various storage time as regards to palmitic acid contents could have been due to the age of the nuts during storage and also due to genetic variability that existed among the nuts, as age variation and genetic variability affects the degree of saturation of the shea butter.

The variations observed for linolenic acid in terms of storage time could be due to genetic variability of the nuts from the different trees they had been obtained. The differences observed in the different storage environments may be due to the differences in environmental conditions; warm climates favor the formation of unsaturated fatty acids. High linolenic acid contents suggest high essential vitamins available in the shea butter.

The variations observed for the interaction between storage time and storage environments on the stearic acid composition of the shea butter might be attributed to genetic variability among the nuts collected from different sources. It may also be due to differences in the storage environments; cold climates favor the formation of saturated

acids. Changes in the temperature of the environments could have caused the variations in oleic acid of the shea butter extracted over time of storage, as warm climates favor the formation of unsaturated acids.

The highly significant variations observed for the interaction between storage time and environment on linoleic acid contents of the shea butter might be due to genetic variability. Similarly, the differences observed for the interaction between storage time and environment on the linolenic acid contents in this study could be due to the differences in environmental conditions, for the nuts being stored. Genetic variability and age variation of the nuts during storage might have caused the difference observed for the interaction between storage time and storage environments.

# CHAPTER SIX

# SUMMARY, CONCLUSION AND RECOMMENDATION

## 6.1 Summary

Shea nuts and its products are increasingly becoming important both in local and international markets. This is because of its numerous importances in which it is used as cooking oil, treatment of various skin blemishes, hair conditioning oil etc.

Shea nuts are of different grades depending on the way in which they are being processed and stored which consequently affect its marketability. How shea kernels are stored or the environment in which they are stored, have a great effect on the quality of the shea butter that will be extracted from the kernels. In view of this, an experiment to study the effect of storage environments and time on shea nuts as it affect the quality of shea butter in Yola was carried out.

A Factorial in Randomized Complete Block Design was used consisting of two factors – storage time and storage environments. The physico-chemical properties and fatty acid composition measured during the experiment were oil yield, density, refractive index, specific gravity, saponification value, unsaponifiable matter, free fatty acid, iodine value, stearic acid, oleic acid, linoleic acid, linolenic acid and palmitic acid.

Based on the parameters measured, storage of nuts for 9 months happened to be most promising in terms of oil yield, linoleic, linolenic, free fatty acids and the saponification value. On the other hand, laboratory storage environment happened to perform very well in terms of oil yield, density, free fatty acid, iodine value, linoleic acid and palmitic acid, as compared to open space storage environment.

## 6.2 Conclusion

Storage of nuts for 9 months before oil extraction happened to be the suitable time to store shea nut before oil extraction. On the other hand, laboratory storage environment was found to be very suitable for storage of shea nuts before shea butter extraction.

## 6.3 Recommendations

Based on the findings of this research, it may be recommended that for a high quality shea butter to be extracted from shea nuts after storage, it must be stored in a well ventilated area, void of any weather elements (like rainfall, high temperature, etc.) that may lead to low quality shea butter. The nuts can be kept for long before butter extraction provided that they are stored well.

The data presented in this study is for one site (Yola) and one season (2009/2010) and need to be replicated over other sites with different environments to verify the findings reported in this research work.

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Appendix 1: Mean square values for the analysis of variance for effects of storage environments and time on the physico –chemical properties of shea butter

| Sources Variation | d.f | Oil yield | Oil density | Refractive Index | Specific gravity | Iodine value | Saponification value | Unsaponifiable matter | Free fatt acid |
|---|---|---|---|---|---|---|---|---|---|
| Replication | 2 | 7.09 | 0.0000014 | 0.00000074 | 0.00000238 | 0.087 | 0.167 | 0.05 | 0.26 |
| Time | 6 | 70.14NS | 0.0041137** | 0.000000865** | 0.00009078** | 0.553* | 11.595** | 0.112** | 36.43** |
| Error (a) | 12 | 54.13 | 0.0000031 | 0.00000038 | 0.00000108 | 0.119 | 0.333 | 0.001 | 0.59 |
| Environment | 1 | 84.15* | 0.0000015NS | 0.000000652** | 0.00000536* | 22.194** | 54.857** | 0.006NS | 45.22** |
| T x E | 6 | 17.98NS | 0.0000693** | 0.00003686** | 0.0006675** | .932** | 52.468** | 0.104** | 8.02** |
| Error (b) | 14 | 13.11 | 0.0000024 | 0.00000038 | 0.00000069 | 0.08 | 0.31 | 0.006 | 0.27 |

** Significantly different P=0.01, * significantly different P=0.05, NS non –significant

Appendix 2: Mean Square values for the analysis of variance for the effects of storage environments and time on the fatty acid profile

| Sources Variation | d.f | Stearic acid | Oleic acid | Linoleic acid | Linolenic acid | Palmitic acid |
|---|---|---|---|---|---|---|
| Replication | 2 | 0.000714 | 0.00381 | 0.000238 | 0 | 0.00071429 |
| Time | 6 | 2.46944** | 1.16476** | 0.376905** | 0.02000000* | 0.07666667** |
| Error (a) | 12 | 0.002659 | 0.00381 | 0.003571 | 0 | 0.00321429 |
| Environment | 1 | 0.380952** | 0.243810** | 0.125952** | 0.0214286** | 0.01166667NS |
| Tx E | 6 | 7.811508** | 0.914921** | 0.087063** | 0.0141286* | 0.02555556** |
| Error (b) | 14 | 0.004286 | 0.004762 | 0.002619 | 0 | 0.00428571 |

** Significantly different P=0.01, * significantly different P=0.05, NS non –significant