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# EFFECT OF DIFFERENT PROCESSING METHODS AND PERIODS OF STORAGE IN DIFFERENT CONTAINERS ON SOME QUALITY CHARACTERITICS OF KERNEL AND EXTRACTED BUTTER OF SHEA NUT

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**BY**

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## DECLARATION

I, hereby, declare that except for references to other people‟s work, which have been duly acknowledged, this write-up, submitted to the school of research and graduate studies, Kwame Nkrumah University of Science and Technology, Kumasi, is the result of my own investigation and has not been presented for any degree elsewhere.

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## ABSTRACT

Shea kernel processing methods and storage are some of the major challenges leading to low quality kernels and shea butter production in Ghana. In this study, fresh shea fruits were collected at Cocoa Research Institute of Ghana substation Bole in Northern Region of Ghana. The fruits were depulped on the same day and nuts washed and divided into two parts. One part was parboiled at 40$^{o}$C for 20 minutes while the other part was not parboiled before putting them into solar driers for drying. Shea kernels were removed from the nuts and dried in solar driers until they attained a moisture content of 7%. Kernel samples were then put into five different storage containers (jute sack, cardboard, polyethylene bag, synthetic fibre and plastic bucket) and stored for seven months. Carbohydrate and crude protein contents were significantly ($p<0.05$) higher but ash content lower in parboiled kernel than non-parboiled. Fat, energy, nitrogen free extract, moisture and crude fibre contents were not different among kernel samples at $p=0.05$. Free fatty acids profile levels were significantly ($p<0.05$) higher in non-parboiled shea kernel than the parboiled while peroxide value was higher in parboiled kernel. *Aspegillus niger* was identified on both parboiled and non-parboiled kernel samples but percentage infection was not significantly different ($p>0.05$). There were significant differences ($p<0.05$) in shea kernels proximate and chemical constituents at seven (7) months storage. Shea butter obtained from the parboiled and non-parboiled kernels were distinctively different from each other in colour, taste and smell. Storage containers did not significantly ($p>0.05$) affect kernel proximate and physicochemical characteristics of the butter except moisture content that kernels kept in polythene bag were higher than those kept in the cardboard. Parboiling of fresh shea nuts before drying and storage period are key determinants of kernel proximate composition and physico-chemical properties of the butter.

## DEDICATION

This thesis is dedicated to my family and the entire workers of Cocoa Research Institute of Ghana, Bole Sub-station.

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I wish to thank my wife and children for enduring with me during my absence from the family to enable me complete this work.

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## LIST OF ACRONMS

ANOVA - Analysis of variance

ARSO- Africa Organization for Standardization

CBE – Cocoa Butter Equivalent

CHO – Carbohydrate

CF- Crude fibre

CFC - Common Fund for Commodities

COVOL- Cooperative Office for Voluntary Organization

CP – Crude protein

CRIG – Cocoa Research Institute of Ghana

FAO- Food and Agricultural Organization

FFA- Free fatty Acids

GBGS- Ghana Board for Grades and Standards

IPGR- International Plant Genetic Resource

MC- Moisture content

PDA-Potatoes Dextrose Agar.

PV- peroxide value

SHB- Ghana Shea Board

UEOMA- Economic and Monetary Union of West Africa States USAID- The United States Agency for International Development

WATH –West Africa Trade HUB

# CHAPTER ONE

## 1.0 INTRODUCTION

The consumption of shea products (kernel, butter and oil) is increasing, especially in their production zone due to the high cost of imported oils (Honfo *et al.*, 2011). In Northern Ghana, shea is an important income earning activity for many rural women and in international market, it is highly demanded due to its richness in food nutrients and other fatty spread (Alander, 2004). The shea butter and oil are obtained from the shea kernel of the shea tree.

Shea tree (*Vitellaria paradoxa*) is a parkland woody tree, which is not commonly cultivated. It grows wild extensively in the dry savannah belt of West Africa, stretching from Senegal in the west to Sudan in the east (Bernice, 2011). In Ghana, the Guinea Savanna, Forest Savanna and Sudan Savanna which cover about two-third of the country‟s land mass is home to the shea tree (Abiw, 1990).

Shea tree is one of many indigenous fruit trees which although undomesticated play an important role in sustaining the livelihoods of people living in rural areas. The fruits of the shea tree consist of a green fleshy mesocarp which has high nutritional value and contains between 0.7 to 1.3 grams of protein and 41.2 gram of carbohydrate (Bernice, 2011). Shea kernel is a rich source of fat (Tano-Debrah and Ohta, 1994).The most important product of (*Vitellaria paradoxa*) is shea butter, which is extracted from the dried kernels (IPGRI, 2006). The butter is used as body cream, fuel in rural lamps and in medicinal preparation (Yeboah, 2009).

On the international market, shea kernel is sold in grades with higher grades attracting premium price. In order to achieve high value of shea products, quality assurance is of great concern. Holtzman (2004) reported that, one could not export shea kernel without having access to high quality products. Presently, shea are exported to France, Great Britain, the Netherlands, Denmark, North America and Japan (Elias & Carney, 2007). Without quality assurance and control, Ghana exporters of shea kernel and butter cannot favorably compete on the international market. Cooperative Office for Voluntary Organization (COVOL) has introduced a strong campaign to improve nut quality, although the system is not generally used in the trade, many traders are aware of the standards being used by COVOL (Ferris *et al*.,2001). Countries such as USA and United Kingdom which import bulk of the shea products have established quality standards. According to ARS SHEA-K (2011), shea kernel is graded as Grade I, II and III depending on the levels of free fatty acid, peroxide value, moisture content and impurities.

The quality of the kernel can be affected by storage conditions. Hall *et al.* (1996) reported that inappropriate storage is the primary reason for the loss of kernel quality. Different kernel storage containers and fresh nuts pre-treatment exist across the shea producing zones (Aculey *et al*., 2012). In Ghana, materials used for storage of kernels are: ceramic pots, synthetic fibre (fertilizer sacks) and jute sacks. The jute sack is the most common storage container used in Ghana.

The fresh nuts pre-treatment (parboiling) is an important primary processing method of shea nuts to prevent seed germination before drying, which is a common practice in shea production zones in Ghana. According to Omujal (2009), variability in proximate, physicochemical and

fatty acid profile due to geographical and environmental conditions have been reported but post-harvest handling practices factors have not been investigated.

The main objective of this study was thus to determine the effect of fresh shea nut processing and storage periods in different containers on some quality characteristics of the kernel and the extracted butter.

The specific objectives of this research were to:

1. determine the effect of different processing methods (parboiling and non-parboiling) of shea nuts on proximate composition and physico-chemical properties of the butter;
2. assess the effect of different kernel storage containers on proximate composition and physico-chemical properties of the butter;
3. assess the effect of relative humidity and temperature on different kernel storage containers and the shea kernel stored in them;
4. assess the influence of processing methods of shea nuts on the fungal infection on the shea kernel; and
5. assess the effect of kernel storage periods on proximate, free fatty acids and peroxide values characteristics.

## CHAPTER TWO

# 2.0 LITERATURE REVIEW

## 2.1 Botany and distribution in Ghana

The shea tree is not domesticated but it naturally grows in the wild and on farmlands, farms and around homes. Shea tree is a small to medium-sized deciduous tree that occurs in a wide swathe of territory above 1° of latitude in tropical Africa (Hall *et al*. 1996). Shea tree belongs to the Sapotaceae family, growing wild in West and Central Africa (Maranz *et al*., 2004). Two subspecies have been identified. *V. paradoxa* sub sp. *Paradoxa* is found in West and Central African (Hall *et al.*, 1996; Salle *et al.*, 1991; Sanou *et al.*, 2005; Fontaine *et al.*, 2004; Kelly *et al.*, 2004), while *V. paradoxa* subsp. *Nilotica* is common in East Africa (Sudan, Ethiopia, Uganda and Republic Demotratic of Congo) ( Okullo *et al.*, 2010). The tree is perennial and deciduous and occurs mainly on dry open slopes (Yidana, 2004).

In Ghana, shea trees (*Vitellaria paradoxa*) grow in abundance in the wild in almost half of the country occurring almost in the entire area of northern Ghana, with land coverage of over 77 670 $km^2$ in Western Dagomba, Southern Mamprusi, Western Gonja, Lawra, Tumu, Wa and Nanumba with Eastern Gonja having the densest stands. It is also reported that in Ghana, it occurs extensively in the Guinea Savannah and less abundantly in the Sudan Savannah (Fobil, 2007). There is sparse shea tree cover found in Brong-Ahafo, Ashanti, and the Eastern and Volta regions in the south of the country (Fobil, 2007). Abdul-Mumeen *et al*. (2013) described the shea tree to attain height of about 6.1 meters and girths of 61 centimeters in the wild when it is often ravaged by bushfires. They can however reach heights of about 15 m and 17 cm girths under protected conditions. The trees grow slowly from seeds, taking about 30 years to maturity (Yidana, 1994). The flower of the shea tree is bisexual, calyx of two whorls

of three to four free sepals with the outer whole valvated. The stamens in the flower range from six to eight in a single whorl inserted at the top of the corolla tube as well as being filament free. The anthers are turned away from the axis (extrorse) (Yidana, 1994). The flower is characterized by staminodes which are well developed alongside some stamens.

Despite the abundance of flowers, only 3 to 5 fruits per inflorescence become ripe (Eneh, 2010). The tree produces fruits and seeds (between May and August) which are sub- globosely to ovoid size of a large plum, pericarp about 1mm thick and exudes white latex when green. It contains a fleshy pulp which is sweet and perfumed when matured. It can be eaten raw when allowed to over-ripe. Fruit contains 1-2 large shining brown seeds.

The kernel is whitish and rich in fats (45-55%) from which is produced shea butter (Ani *et al*., 2012). The principal constrains are: long juvenile phase, genetic variability and lack of knowledge regarding the cultivation of the species (Dembele *et al*., 2004). Potential productivity of trees is influence by genetic variability and by external factors still, to be identified (Boffa, 1995)

## 2.2 Economic importance of Shea tree

The shea tree has proved to be very resourceful in tropical Africa and has been recommended among other trees like *Parkia* species as products priorities that need funding for development (FAO, 1989).The fruits are common food for both children and adults. Additionally, the tree produces caterpillar, which serves not only as nutritious food but also as a source of income to rural women. For instance, among the Tivs in Benue State, the caterpillar got from the shea butter tree, known in Tiv language as “IGYU” is specially prepared with sauce and serves as a

special delicacy and is found marketed along the streets (Ani *et al*., 2012). Kent and Bakaweri, (2010) noted that the shea kernels are high in oils and have long been collected and processed by women in Savannah communities, where they provide a useful source of fat in the diets.

The kernels are processed into shea butter and pressed cake. The tree gains important as an economic tree crop because of the heavy demand for its butter both locally and internationally (Abdul-Mumeen *et al*., 2013). Food processing in general involves synergism between different physical processes to transform raw animal/plant materials into consumer-ready products (Norton and Sun, 2008). The vegetable fat of shea nut was reported by Hall *et al*., (1996) is second in importance only to palm oil in Africa. The commercialization of Shea products represents an important source of income to different individuals (Boffa *et al*., 1996).Shea nut industry has contributed immensely to the economic growth of the Northern part of Ghana (Abdul-Mumeen *et al*., 2013).The unstable world market price for cocoa has resulted to the need to find a suitable substitute to cocoa in the confectionery and cocoa butter industry hence making shea tree and product economically important since 1970"s (Dogbevi, 2009). Shea butteris used in food, soap, cosmetics, and in chocolate formulations (Diarrassouba *et al*. 2005).The uses of shea butter obtained from shea nuts are numerous and as such, it uses can be grouped into industrial, domestic and medicinal use.

### 2.2.1 Industrial importance

Industrially, countries such as France, Great Britain, the Netherlands, Denmark, North America and Japan are the main importers of shea (Carette *et al*., 2009). In 2003, European

Union accepted shea butter as one of the six vegetable fats to serve as a Cocoa Butter Equivalent (CBE) (Schreckenberg, 2004). As a result, Shea nut is processed into a wide range of food products including chocolate and it is now also commonly used in the cosmetic industry. The major market of shea butter has been found in chocolate and confectionary industries and there is fast-growing, popular market in cosmetics and personal care product industry (Alander, 2004).

Shea tree has a great-untapped capacity for producing large amounts of sap that can constitute an important source of raw material for the gum and rubber industry. It is known that the mature kernel contains about 61% edible fat and can be used for medicinal as well as industrial purposes (Dogbevi, 2009). Shea pulp contains ascorbic acid (196 mg/100 g), iron (2 mg/100 g) and calcium (36.4 mg/100 g) and the shea pulp is a rich source of sugars, proteins, calcium and potassium (Maranz *et al*. (2004).This suggested that shea need serious consideration for developing programs.

### 2.2.2 Domestic and nutritional value

*Vitellariaparadoxa* is one of many indigenous fruit trees although undomesticated play an important role in sustaining the livelihoods of people living in rural areas. The fruits of the shea tree consist of a green fleshy mesocarp which has high nutritional value and contains between 0.7 to 1.3 grams of protein and 41.2 gram of carbohydrate (Bernice, 2011). The shea fruit is an important source of food for rural communities especially at times of food shortages, hunger and other disasters in addition to providing enormous health benefit and income, hence it could help alleviate hunger in rural area during and after it‟s ripening season (Bernice, 2011; Aguzue

*et al*., 2013). For the people of Northern Ghana, the fruits serve as hunger stopgaps as they come in fruition during the lean season when food is very scarce, and many local communities particularly children and women who are the most vulnerable depend on the pulp for food to survive the critical hunger periods while pending the harvest of early maturing crops such as millet and the like. The consumption by humans is localized and therefore, there is no commercial and industrial utilization for the fresh fruit.

Shea kernel is a rich source of fat (Tano-Debrah and Ohta, 1994). Nutritious unsaturated fatty acids such as oleic and linoleic fatty acids and fat soluble vitamins are found in the oil obtain from the shea kernels (Karin, 2004; Kapseu, *et al.*, 2007).The most important product of (*Vitellaria paradoxa*) is shea butter which is extracted from the dried kernels (IPGRI, 2006). The butter is used as body cream, fuel in rural lamps and in medical preparation (Yeboah, 2009). The solid fat (butter or stearin) and the liquid oil (olein), are ideal for use as raw materials in cooking oil, margarine, cosmetics, soap, detergents and candles (Fintrac, 1999)

### 2.2.3 Medicinal importance

Shea butter stands out because of its high fraction (about 8%) of content with medicinal properties. It contains essential fatty acids, and helps to protect and revitalize damaged skin and hair. Shea butter has high moisturizing and emollient properties which could help improve drying skin and hair. Products such as lip balms, hand creams, facial moisturizers, shampoos and conditioners could be made from shea butter. It is known to be naturally rich in vitamins A, E, and F, and other vitamins and minerals. Vitamins A and E help to smooth, hydrate, and balance the skin (Dogbevi, 2009). They also provide skin collagen acting as antiagents for

wrinkles and other signs of ageing. Shea butter is a perfect dry skin moisturizer and is also an effective product in a form of cream for revitalizing dull or dry skin on the body or scalp. It is a good agent for skin renewal, increases circulation, and accelerates wound healing and for the treatment of many other ill conditions (Dogbevi, 2009). Shea butter has relatively higher unsaponiifiable matter s compare to other vegetable fats and oils (Alander, 2004). The unsaponifiable fraction of shea butter is used as ingredient in the treatment of inflammatory diseases due to its anti-inflammatory action (Masters, 2004)

### 2.3 Physico-chemical properties of shea kernel and butter

Tano-Debrah and Ohtaa (1994), reported proximate composition of the kernel on dry-matter basis as: total lipids, 59.04%; crude fat, 54.85; protein, 7.81%; total carbohydrates, 34.77%; ash, 2.57%. Starch content was 7.59%; hemicelluloses, 10.84%; cellulose, 5.95%; and pectic substances, 2.93%. Total fiber content was 20.35%. The fat extracted by the Soxhlet method was pale-yellow in color and solid at room temperature.

Shea butter oil is still considered second to palm oil as the most important source of cooking fat, particularly by West African rural dwellers(Aguzue *et al*., 2013).Shea butter physicochemical characteristics according to (Obibuzor *et al*., 2013), melting range was (34–36 °C); iodine value (58.53%); saponification value (180.37%); and unsaponifiable matter content(7.48%). The predominant fatty acids found by Obibuzor *et al*., 2013 were: palmitic(3.55%), stearic (44.44%), oleic (42.41%), linoleic (5.88%) and linolenic (1.66%) acids. Variation in physicochemical properties of shea butter from ungerminated and germinated kernel was reported (Obibuzor et al., 2013). Butter yields were 52 and 49% from

ungerminated and germinated respectively. The physicochemical properties of butter from the ungerminated and germinated nuts were free fatty acid (FFA) (0.22 and 1.66%), saponification value (SV), (223 and 239 mgKOH/g), unsaponifiable matter (7.77 and 9.39%), iodine value (Wijs) (IV) (33 and 30), and peroxide value (PV) (0.10 and 8.14 meq/kg), respectively.

The chemical compositions of West Africa shea butter according to Nahm (2011) were: palmitic (3.36-4.44 %), stearic (39.74-44.62 %), oleic (40.71-44.48 %), and linoleic acids (5.73-6.41 %). Shea butter fatty acids are composed dominantly of palmitic (16:0), stearic (18:0), oleic (18:1), and linoleic (18:2) acids. Stearic and oleic acids dominate almost 40 - 45 % of total fatty acids respectively and linoleic acid generally ranges from 5-10 %, followed by palmitic acid at 4 % with lower amounts of arachidic acid and others. According to megnanou *et al*. (2013), shea butter physicochemical characteristics are influenced by the roasting time because the acid, peroxide, iodine index and unsaponifiable content varied considerably with roasting time. Boiling treatment resulted in more free fatty acids (FFA) (6%) and a higher fat content (41%) of kernels (Honfo *et al*., 2013). Aguzue *et al*. (2013) reported that chemical analysis of shea butter extracted from nuts samples from four African countries: Uganda, Nigeria, Burkina Faso and Mali confirmed the considerable variability in shea oils across African. The Uganda oil had a 59% oleic acid content compared with only 39% for Burkina Faso.

**2.4 Processing of Shea Kernel and shea butter**

The fruits of shea matured between April and June and is allowed to fall, and is harvested by collection from the ground around the trees. Women usually collect and heap she nuts until they have sufficient quantity for boiling and this affect the quality of shea kernel produced

(Kent and Bakaweri, 2010) The fruit pulp is removed by allowing it to rot or dry (Bernice, 2011). The fragile shell is similarly removed by cracking and winnowing and the nut (kernel) sun dried before storage. The kernels are dried to reduce the moisture content from about 40% to about 7% (Fintrac, 1999).

In West African boiling of the nuts (parboil) are usually done to kill the embryo and thus prevent germination of the seeds. This method has the additional advantage of inactivating the lipases that are responsible for hydrolytic degradation of shea butter (Nahm, 2011). Because of the presence of lipase enzymes in the living shea kernel, in post-harvest processing, the kernel should be quickly killed by parboiling (control boiling) before drying in order to make the kernel chemically stable and be stored without further chemical processes affecting the lipid content (ARS SHEA-C 2011).

Traditionally, there are eight unit operations in the primary processing of the shea fruit in Ghana for the marketable kernel viz collection of fruit, storage of fruit, de-pulping of nut, parboiling, drying of nut, cracking of nut and separation of kernel, drying of kernel, bagging and storage of kernel. Among these, par boiling and drying have been reported as paramount (Lovett, 2004; Aculey *et al.*, 2012). Perakis, (2009), reported that in Mali two shea nuts drying methods are used to prepare nuts for storage, further processing and marketing: " bury and roast" or "boil and sun-dry". The common practice in Mali is bury and roast method. The processing methods, kernel storage and phytosanitory conditions are some of the major challenges leading to production of low quality shea butter (Obibuzor *et al*., 2013). Postharvest processing (parboiling), quickly kills the seed and enhance drying of the kernel making the

kernel chemically stable for storage without further chemical processing processes affecting the lipid content leading to rancidity. According to Perakis (2009), “boil and sundry” method is preferred to bury and roast method by exporters and the international communities. Another innovation was a locally made oven dry method which is more preferable. However, these practices (heat treatment of fresh shea nuts) are artisanal, leading to highly heterogeneous final product. Aculey *et al*., (2012) reported that parboiling induces physical changes in the structure and colour of the shea kernel and the possible formation of volatile aromatic compounds.

Traditional processing of shea butter involves crushing the nuts and boiling them in water. The shea butter is skimmed from the surface where it is collected (Eneh, 2010). A report by USAID (2004) identified three methods of extracting the oil: namely traditional boiling, mechanical pressing (either manual or hydraulic) and solvent extraction. According to Eneh (2010), the shea butter processed from traditional method is unsuitable for export and is therefore sold and consumed locally. The traditional processing method is laborious, time consuming process using large quantities of water and firewood (Omajul, 2009; Swetman *et al*., 1997) and the product is of low quality and fetches low income for processors (Eneh, 2010). Ofosu (2009) reported an average yield of butter by using traditional method of extraction to be about 30%. Carette *et al*. (2009) reported that 1 kg of shea butter was obtained from 3 kg of shea kernels (33.3%) during manual extraction. When more efficient method of extracting the oil is used higher oil percentage is obtained (Obibuzor *et al.*, 2013). However, Nahm (2011) on the other hand revealed that, with the increased interest in naturally derived products, organic shea butter production is preferred and thus efforts have been made to industrially produce shea butter by following the traditional extraction methods.

## 2.5 Storage of Shea Kernel

Volume of shea kernels that goes to the processors is consumed but that goes through the itinerant traders during the peak season mostly ends up being stored by the assemblers and wholesalers to profit from scarcity during the lean periods (Ferris *et al*., 2001). Producers use a wide variety of storage methods often unsound (Masters, 2002) It is a known fact that storage conditions of Shea kernel are key constraints for the quality assurance of the shea butter. Shea nuts (kernels) are stored in a host of different receptacles ranging from clay storage bins and baskets for kernels solely use within the house hold setting or plastic and burlap bags if the kernels are for marketing (Perakis,2009). In West Africa especially Ghana, Jute bags from cocoa industry are widely applicable. Over the past decades, polythene bags or sacks have come into wide use for storage of shea kernels in Uganda (Omujal, 2009) but the recalcitrant properties of shea nuts, makes it storage very difficult (Karin, 2004). Burlags bags are recommended for storing shea kernel in Mali as they allow moisture to escape, reducing the possibility of pervasive molding another source of possible quality deterioration (Perakis, 2009).

## 2.6 Marketing of Shea Products

On the international market, Shea kernel is sold in grades with higher grades attracting premium price. In order to achieve the value of shea products, quality assurance is of great concern. Holtzman, (2004) reported that, one cannot export shea kernel without having access to high quality products. Presently shea is exported from Africa to France, Great Britain, the Netherlands, Denmark, North America and Japan (Elias and Carney, 2007). Without quality

assurance and control, Ghana exporters of shea kernel and butter cannot favorably compete with others in the international market. One of the factors that contribute to poor quality of Shea kernel is storage. The leading shea producers and exporters include Burkina Faso, Mali, Ghana, Nigeria, Côte D"Ivoire, Benin, Togo and Guinea. Exports of shea nuts from these countries have increased dramatically in recent years, from 50,000 tons in 1994 to 150,000 in 2004 and finally to 350,000 in 2008 with Ghana alone exporting 50,000 tons in 2008 (Lovett et al., 2005).

## 2.7 Quality Standards of Shea Kernel and Butter

Quality of butter is a function of the quality of nuts which in itself is a function of nuts collected from the field and the process of parboiling and drying (Anchirinah *et al*., 2012). According to Fintrac (1999), individual companies specify their own quality standard for purchase of the shea nuts. The following is a 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%. ARS SHEA-K ( 2011), shea kernel is graded as Grade I, II and III depending upon the levels of free fatty acid, peroxide value, moisture content and impurities. In addition, consumers judge food quality based on the sensory and nutritional characteristics such as texture, flavour, aroma, shape, colour, calorie content, vitamins as well as shelf life (Norton and Sun, 2008).Establishment of standards for shea kernels and butter is seriously advocated. COVOL had introduced a strong campaign to improve nut quality and although the system is not generally used in the trade market, many traders are aware of the standards being used by COVOL (Ferris *et al*., 2001). Quality standard for unrefined shea butter has been developed by ProKarité, a project managed by the World Agroforestry Centre and funded by CFC/FAO

(Common Fund for Commodities/Food and Agriculture Organization) and approved by UEMOA (Union Economique Monétaire Ouest Africaine) (Lovett *et al*., 2005).



According to Megnanou and Niamke (2013), standards for shea butter are subdivided into quality (moisture, acid and peroxide value), distinctive or typical (melting point, saponifiable, iodine and refractive index) and mineral (absence of heavy metals). Studies underlined the impact of raw material treatment on resulting products quality are many (Megnanou and Niamke, 2013). Certification of shea kernel and butter has become increasingly important (USAID 2004) and therefore there is an urgent need to take quality measures in the supply chain. Tables 2.1 and 2.2 indicate quality requirement of shea kernel and butter.

Table 2.1: Specific requirement for shea kernel quality

| Parameters | **Grade 1** | **Grade 2** | **Grade 3** |
|---|---|---|---|
| | **Max** | **Min. Max.** | **Min.Max.** |
| Moisture content (%) | 0.5 | > 5-7 | > 7 – 8 |
| Free fatty acid (%) | 2 | > 2 – 4 | > 4 – 5 |
| Peroxide value (meq/kg) | 5 | >5 – 7 | >9 – 15 |

| | | | |
|---|---|---|---|
| Insoluble impurities (%) | 0.5 | >0.5-0.8 | > 0.8-1 |

Source: ARS SHEA-K (2011)



Table 2.2: Quality characteristics and grades of unrefined shea butter

| Parameters | Unrefined shea butter | | |
|---|---|---|---|
| | **Grade 1** | **Grade 2** | **Grade 3** |
| | **Min. Max** | **Min. Max** | **Min.Max** |
| Moisture content (%) | - 0.05 | > 0.05 – 0.2 | > 0.2 – 2.0 |
| Free fatty acid (%) | - 1.0 | > 1.0 – 3.0 | > 3.0 – 8.0 |
| Peroxide value (meq/kg) | - 10.0 | >10.0 – 15.0 | >15.0 – 50.0 |
| Insoluble impurities (%) | - 0.09 | >0.09 – 0.2 | > 0.2 – 2.0 |

Source: Regional Technical Committee Comments on Draft Africa Regional Standard for Unrefined Shea Butter (2006).

### 2.8 Factors affecting quality of Shea Kernel and Butter

Quality of fats and oils is dictated by several physical and chemical parameters that are dependent on the source of oil; geographic, climatic, and agronomic variables of growth in the case of plant oils as well as processing and storage conditions (Obibuzor *et al*., 2013).

Changes in the expression of various fatty acids metabolizing enzymes can result in changes in the kernel oil compositions (Napier, 2007). The quality of shea nuts and butter are basically dependent upon post-harvest processing (Omujal, 2009). High temperature and residual water in kernels would not only induce hydrolysis reactions of glycerides but also the oxidation of

unsaturated fatty acids (Kajimoto *et al*., 1986). Aculey *et al*. (2012) observed that, high temperature and humidity greater than 65%, poses the nuts to a wide range of moulds infection. Mouldiness of kernels reduces the quality of the kernels. Oxidation and hydrolysis reactions could be induced by air oxygen, sun rays or any other heat source (Hall *et al*., 1996; Megnanou and Niamke, 2013). High moisture content in plant fats and oils usually leads to increase in microbial load as well as lipid oxidation resulting in rancidity (Nahm, 2011).

Free fatty acid (FFA) content is an indication of deterioration in an oilseed or oil - hydrolysis of the triglyceride to produce un-esterified fatty acids - it is a standard measure used in commodity trading specifications (Fintrac, 1999). Geographical variation appears to influence fatty acid composition of shea butter (Nahm, 2011). The quality of shea kernel is determined by the level of free fatty acids, the lower it is, the better the butter produced. Inadequate storage is the primary reason for the loss of kernel quality (Hall *et al*., 1996). Better quality is obtained by sun-drying of the shea nut and avoidance of smoking since smoking the nuts over a fire contaminates it with hydrocarbons (Nahm, 2011). According to Obibuzor *et al*., (2013), the processing methods, kernel storage and phytosanitory conditions are some of the major challenges leading to production of low quality shea butter. It is therefore important to consider various factors that lead to poor quality shea nuts products in order to promote shea products commercialization locally and internationally

## CHAPTER THREE

# MATERIALS AND METHODS

## 3.1. Study Location

The studies were carried out at Bole and Kwame Nkrumah University of Science and Technology, Kumasi. The main experiment was conducted at the CRIG Substation, Bole, which is located in the extreme western part of the Northern region of Ghana within the Guinea Savannah Agro-ecological zone which lies between latitude N $8^0$ 10‟ 5 and 09‟ and longitude $1^0$ 50‟E and $2^0$ 45‟ W. The experiment commenced in the shea harvesting season in July 2013 and ended in February 2014. Temperatures and relative humidity conditions in the storage materials, storehouse and outside during the storage period were monitored (Appendix 1A). Color, aroma and tastes characteristics determination of extracted Shea butter were done at the CRIG substation, Bole. Proximate analysis, fungi identification and chemical analyses were done in the laboratories of KNUST and Natural Renewable Resources, Kumasi.

### 3.1.2. Sample Collection and preparation

Shea kernels were obtained from two different primary processing methods of the fresh nuts (parboiling and non-parboiling). Fresh fruits were collected from CRIG, Bole substation‟s shea plantation and depulped mechanically. One group of the nuts was parboiled at 40$^o$c for 20 minutes and the other not parboiled before drying in solar driers for three days. The nuts were then cracked mechanically and kernels separated from the shells. Kernels were collected into solar driers and dried till moisture content of 7% was attained. 65kg weight of kernels from each source (parboiled and non-parboiled) was then taken for the experiment. In each group, 4kg of the kernels was processed by traditional method into butter at Bole and the butter

samples were taken to Natural Renewable Resources laboratory, Kumasi for physicochemical analysis. One kilogram (1kg) of the kernels was also taken for proximate and fungi determination and identification at KNUST before storage. The remaining 60kg of the Kernels from each of the two fresh nuts processing methods (parboiled and non-parboiled) was divided into 4kg and put into each of the five different storage containers (cardboard, plastic bucket, synthetic fibre, polythene bag and jute sack). Each of the storage containers were replicated three (3) times.

The flow diagram below explains how the fresh shea nuts were processed to kernels before putting into the five different storage containers (A=Parboiling method and B=Nonparboiled).

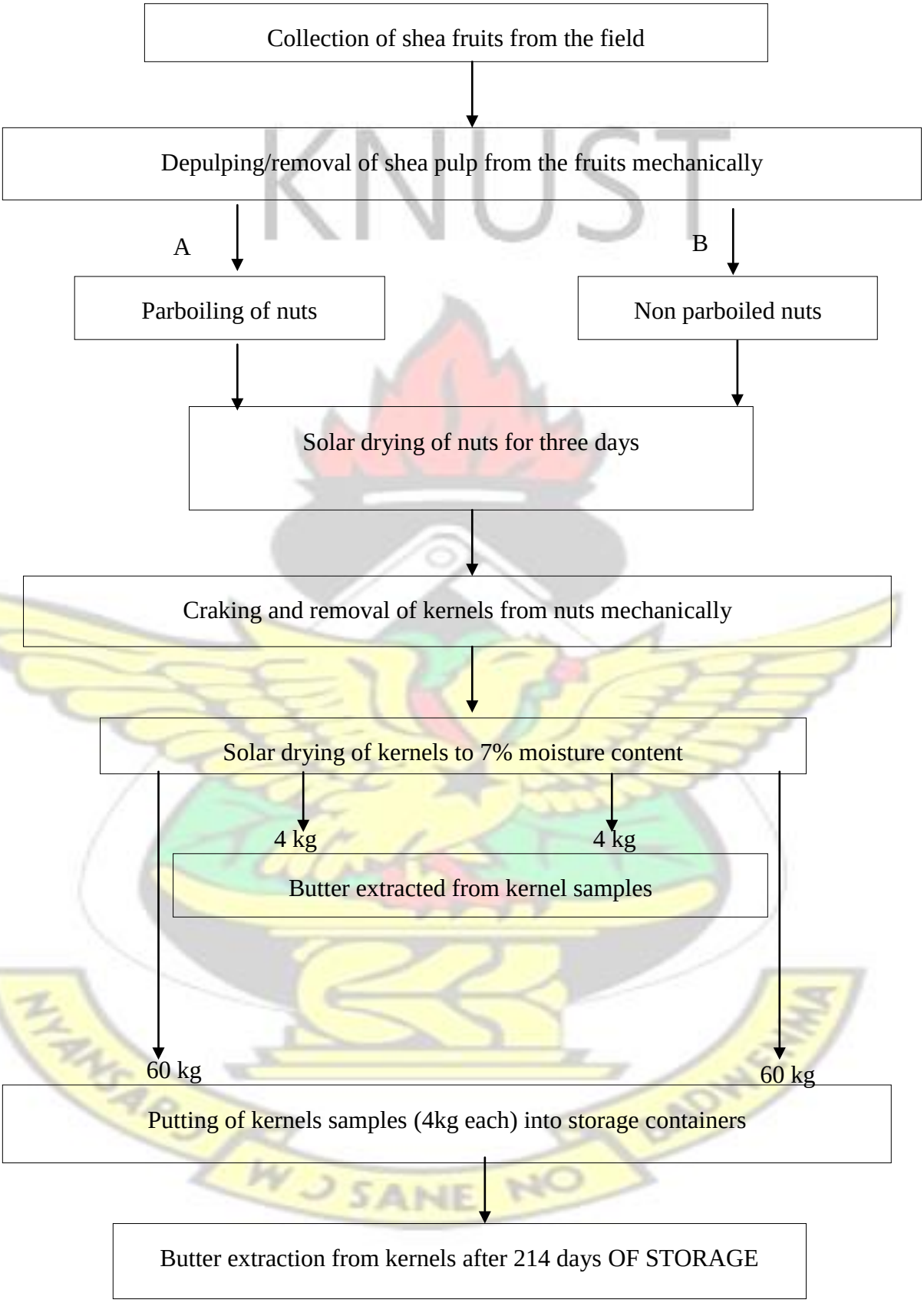
Collection of shea fruits from the field
Depulping/removal of shea pulp from the fruits mechanically
A
B
Parboiling of nuts
Non parboiled nuts
Solar drying of nuts for three days
Craking and removal of kernels from nuts mechanically
Solar drying of kernels to 7% moisture content
4 kg
4 kg
Butter extracted from kernel samples
60 kg
60 kg
Putting of kernels samples (4kg each) into storage containers
Butter extraction from kernels after 214 days OF STORAGE
A kernel
B kernel

Figure 3.1: Diagram of two processing methods of fresh shea nuts to kernels.

Plate 3.1: Parboiled Shea Kernels

Plate 3.2: Non Parboiled Shea Kernels


Plate 3.3: Five Storage Materials Used

Plate 3.4: Experimental layout

### 3.1.3 Storage materials preparation

Cardboards with thickness of 2.56mm and transparent polyethylene bags (0.01mm thick) were obtained from CRIG Substation, Bole cashew processing plant stores. Synthetic fibre sacks (0.62mm), Jute sacks (0.64mm) and plastic buckets (2.08mm) were bought at Bole market. The jute sacks and synthetic fibre sacks were reduced in size by a sewing machine. All the materials were sterilized by spraying with fungicide to ensure fungi – free environs.

### 3.2 Storage procedure

There were five different storage materials replicated three times for each of the parboiled and non-parboiled kernels. The moisture content of kernels was taken using digital moisture meter (National Instrument 8/9, Gunatit). Kernels were then weighed 4kg by using weighing scale with 0± 0.01g accuracy and put into each of the storage material. Data loggers were placed among the kernels inside the storage materials to record temperature and relative humidity within. Another data logger was placed in the storehouse. The storage materials with the content were then placed on raised wooden pallets of 15cm high from the floor in the storehouse. The treatments were observed for seven (7) months, ($15^{th}$ July, 2013 to $16^{th}$ February, 2014).

### 3.3 LABORATORY ANALYSIS

Samples of various experimental materials were taken to the KNUST and Renewable Natural Resources laboratories in Kumasi for analysis of various parameters.

### 3.3.1.1 Determination of Shea kernel moisture content

The shea kernel moisture content was measured by using digital moisture meter (National Instrument 8/9, Gunatit) at the experimental site before storage. Moisture content was again determined as part of kernel proximate constituent in the laboratory by using A.O.A.C method (A.O.A.C, 1997)

2 g of each shea kernel sample was weighed and placed in a pre-weighed moisture can and dried to a constant weight at 105°C in a drying oven. The moisture content of each sample was determined by the formula

$$\text{Moisture content (\%)} = \frac{weight\ of\ fresh\ sample - weight\ of\ dry\ sample}{weight\ of\ fresh\ sample} \times 100 \quad \text{…….(1)}$$

### 3.3.1.2 Determination of shea kernel crude protein content

The crude protein content of shea kernel was obtained according to the Kjeldahl Method, (A.O.A.C, 2002). 2g of each shea kernel sample was weighed and placed into a 500 ml long necked kjeldahl flask and10 ml of distilled water was added to moisten the sample. One spatula full of kjeldahl catalyst (mixture of l part Selenium + 10 parts $CuSO_4$ + 100 parts $Na_2SO_4$) was then added. 20 ml concentrated $H_2SO_4$ was added to digest the sample until the fluid was clear and colourless. The flask was left to cool and the fluid decanted into a 100 ml volumetric flask and distilled water added to make up to the 100ml mark.

**Distillation**

An aliquot of 10 ml of digested fluid was transferred by means of pipette into a kjeldahl distillation apparatus. An amount of 90 ml of distilled water was added to make it up to 100 ml in the distillation flask and 20 ml of 40% NaOH added and placed in a distillation unit. The

distillate was collected (100 ml) over 10 ml of 4% Boric acid containing three (3) drops of mixed indicator in a 200 ml conical flask.



**Titration**

100ml of the distillate collected was titrated with 0.1 N HCl until blue colour changes to grey and then suddenly flashes to pink. A blank determination was carried out without the sample.

**Calculation**

The weight of 2g sample used, the dilution and the aliquot taken for distillation were considered in the crude protein calculation. The weight of the sample used was determined as:

$$\text{Weight of sample used} = \frac{2g \times 10\ ml}{100\ ml} = 0.2\ g \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Thus, the percentage of Nitrogen in the Shea kernel is,

$$\%\ N = \frac{14 \times (A-B) \times N \times 100}{1000 \times 0.2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Where:

A = volume of standard HCl used in the sample titration

B = volume of standard HCl used in the blank titration

N = Normality of standard HCl

% Crude Protein (CP) = Total Nitrogen ($N_T$) x 6.25(Protein factor) .....(4)

### 3.3.1.3. Determination of shea kernel fat content

Determination of fat content of shea kernels was carried out using A.O.A.C method (A.O.A.C, 2002). 2 g of grounded shea kernel was weighed into an extraction thimble. The thimble was placed inside the Soxhlet apparatus. A dried pre-weighed solvent flask was connected beneath the apparatus and 200ml of petroleum ether was added and connected to condenser and extracted for 4 hrs. On completion, the thimble was removed and the ether reclaimed using the apparatus. The removal of ether was completed on a boiling water bath and the flask dried at 105°C for 30 min. it was cooled in a desiccator and weighed. The percentage crude fat of each sample was determined as:

Ether extract (fat) (% of DM) $\frac{weight\ of\ fat}{weight\ of\ sample} \times 100\%$ …….(5)

### 3.3.1.4. Determination of shea kernel crude fibre content

Crude fibre content of the kernel samples were measured by using A.O.A.C (2002), method.

2 g of dried, fat-free shea kernel sample was transferred into a digestion flask. 200 ml of hot 1.25% sulphuric acid was added and the digestion flask was placed under a condenser and brought to boiling within 1 min. The mixture was then boiled gently for exactly 30 min and filtered immediately through a linen cloth and washed with boiling water. The residue was transferred back into the digestion flask and 200 ml of hot 1.25% sodium hydroxide solution added. The mixture was placed under the condenser and again brought to boil within 1 min. After boiling for exactly 30 min, it was filtered through porous crucible and washed with boiling water and about 15ml of 95% alcohol. Then the mixture was dried at 105°C until constant

weight obtained, cooled, and weighed. The residue was ashed at 550°C for 30min, cools, and weighed.



The weight of fibre was calculated by difference as:

$$\text{Crude fibre (\% of DM)} = \frac{(\text{weight of crucible+dried residue}) - (\text{weight of crucible+residue})}{\text{weight of sample}} \times 100\% \quad ...(6)$$

### 3.3.1.5. Determination of shea kernel Ash content

Ash content of shea kernel was determined using the Kjedahl method (A.O.A.C, 2002). An amount of 2 g of shea kernel sample was weighed into a dried, tared porcelain dish and then place in a muffle furnace at 550°C for 4 h. Then mixture was cooled in a desiccator and weighed. The total ash content was determined as:

$$\text{Ash} = \frac{\text{weight of ash}}{\text{weight of sample}} \times 100\% \quad ..... (7)$$

### 3.3.1.6. Determination of shea kernel nitrogen-free extract (NFE)

Nitrogen-Free Extract (NFE) represents the non-structural carbohydrates such as starches and sugars, and was found by difference. NFE was determined by calculation after the determination of the various components of the proximate analysis using the formula below:

%NFE (on dry matter basis) = 100 – (%CP + %CF + %Ash + %EE)……. (8)

Where, NFE = nitrogen free extract, DM = dry matter

EE = ether extract or crude lipid

CP = crude protein

CF = crude fiber



### 3.3.1.7. Determination of shea kernel calorific value /Energy (Kcal/100g)

The total energy of the various treatments was also determined by calculation using the values determined for protein, NFE and fat in the formula below:

Energy (Kcal/100g) = (4 x % Protein) + (4 x % NFE) + (9 x % Fat) ……(9)

### 3.3.1.8. Determination of shea kernel carbohydrate content

The determination of percentage total carbohydrate was carried out using the values obtained for NFE and crude fibre in the formula below:

% Carbohydrate = $(\%NFE + \%\ Fibre)$ ……. (10)

### 3.3.2. Isolation, identification and percentage mould infection on shea kernels

#### 3.3.2.1 Media and sample preparation

One litre of Potatoes Dextrose Agar (PDA) was prepared from CMO13 Oxoid dehydrated PDA and was sterilized by autoclaving at -121 ºC for 15 min at pressure of 0.98kg/m$^2$. The medium was allowed to cool to about 45ºC. Thereafter, the PDA was poured into sterile-Petri plates and incubated at room temperature for 24h to rule out contaminated plates. Sections were cut from

shea kernel and immersed in 4% of Chlorox for 30s. The immersed sections were transferred into sterile distilled water with the aid of sterile forceps to rinse excess Chlorox. Sections (samples) were further transferred onto a sterile blotter paper to dry and then transferred onto the sterile PDA. The plates were incubated at room temperature until growth occurred.



#### 3.3.2.2. Fungi identification and kernel infection percentage.

Seven days after incubation, the dishes were examined for the types of fungi and infection level with the aid of a microscope and reference manuals (Barnett and Hunter, 1972; Mathur and Kongsdal, 2003).

### 3.3.3. Determination of physico-chemical characteristics of shea butter

#### 3.3.3.1. Sensory evaluation

Sensory profiling or descriptive analysis methods consist of formal procedures for assessing, in a reproducible manner, specific attributes of a sample and rating intensity on a suitable scale (Ayamdoo *et al*., 2014). The intensity of sensory perception can be registered quantitatively on a response scale (ISO, 1994). These methods can be used for evaluating aroma, flavor, appearance and texture separately or in combination (ISO, 1994).

#### 3.3.3.1.1 Determination of shea butter taste

Shea butter taste was determined by sensory evaluation. A five-member panel (trained), two females and three males were given a small amount of each butter sample, placed in a plastic

container for each panelist to score taste characteristics on a scale 0-3. The taste was scored as: 0→No bitterness, 1→Mild bitterness, 2→bitter, 3→Very bitter. The figures were converted into percentages (Ayamdoo *et al*., 2014).



#### 3.3.3.1.2 Determination of shea butter aroma/smell

The same panelists were used to score aroma/smell characteristics on a scale 0-3. The smell score was: 0→No nutty smell, 1→mild nutty smell, 2→Nutty smell, 3→Strong nutty smell. The figures were converted into percentages (Ayamdoo *et al*., 2014).

#### 3.3.3.1.3 Colour determination

Shea butter colour was measured using colour charts designed by HMLT (2013). Shea butter was placed on a transparent polythene sheet and placed side by side with the colour chart and the matching done. The five panelists determined the colour independently. The highest colour tipped for each of the sample was taken as the colour of the butter (ISO, 1994)

### 3.3.4 Chemical analysis of shea butter

#### 3.3.4.1. Shea butter free fatty acids (FFA) determination

Free fatty acids values were determined by using A.O.A.C method (A.O.A.C, 1997)

Shea butter sample of 1g was weighed into a titration vessel. The sample was dissolve into 50 ml of solvent mixture (1:1ethanol and diethyl ether). Phenolphthalein solution (0.2ml) was

added and titrated while shaking with 0.1N potassium hydroxide solution until a pink colour persisted for at least 10 seconds. Simultaneously, a blank test was carried out without any sample. Free fatty acids of the various samples were determined by the calculation as:

Free Fatty Acid % = $\frac{ml\ KOH \times N \times MW\ (fatty\ acid)}{10 \times weihgt\ of\ sample}$ .....(12)

Where: N=normality of KOH (0.1N), mLKOH

=titre value of KOH used,

MW= molucalar weight of fatty acid.

Calculations for different components of the free fatty acid values were determined by substituting each of the acid molucular weigt in equation 12 using the following molecular weights:

MW of oleic = 282, MW of palmitic = 256, MW of stearic = 184, MW of linoleic= 280, MW of linolenic = 278

**3.3.4.2. Shea butter Peroxide value determination**

The peroxide value of shea butter samples were determined by using the A.O.A.C method (A.O.A.C, 1997). 3g of shea butter was weighed into a 250 ml Erlenmeyer flask. The sample was dissolved with 10 ml of chloroform by swirling the solution-sample mixture. Then 15 ml of acetic acid and 1 ml KI solution were added and the mixture placed in a dark place for 15 minutes. After the 5 minutes period, 30ml of distilled water and 1ml starch solution were added and titrated with 0.01N sodium thiosulfate until blue colour disappeared. A blank determination

was carried out without a sample. The peroxide value of the various samples was determined as:

$$\text{PV (meq./kg)} = \frac{(V1-V0) \times T \times 1000}{m} \quad \ldots\ldots\ldots\ldots\ldots\ldots(13)$$

Where:

PV (meq./kg) = peroxide value in mili-equivalent available oxygen per kilogram sample $V_1$ = volume of thiosulfate solution required to titrate the sample (ml);

$V_0$ = volume of thiosulfate solution required to titrate the blank determination

(ml); T = titre of the sodium thiosulfate solution (normality); m = mass of sample

(g)

### 3.3.5 Measurement of temperature and relative humidity in the storage containers

The temperature and relative humidity inside the storage containers were recorded by using Cintag Data loggers (TGP 4500) with internal temperature range of -25 $^{o}$C – + 85 $^{o}$C and relative humidity range of 0 – 100% (Appendix C plate 6). Temperature and relative humidity at the experimental site (CRIG, Bole) during the storage period were also obtained from the meteorological station at CRIG-Substation, Bole.

### 3.3.6 Experimental design

The trial was laid in 2x2x5 factorial in a completely randomised design and replicated three (3) times. The factors were: two processing methods of shea nut (parboiling and nonparboiling);

two storage periods (0, 7 months); and storage containers (cardboard, synthetic fibre, plastic bucket, and polythene bag and jute sack).



### 3.3.7 Statistical analysis

Data obtained from the experiment were summarised in Microsoft Excel (92-2003) and imported into Genstat 2007 release7.2 analytical software. The means were compared using the analysis of variance (ANOVA) and Fisher PLSD at 5% significant difference level. Tables and graphs were used to explain the results of the analysis.

# CHAPTER FOUR

# 4.0 RESULTS

## 4.1. Baseline Data

Shea kernels and butter were obtained from parboiled and non-parboiled fresh shea nuts and analyzed for proximate composition, fungi infection and physico-chemical properties. Kernels were then stored under different conditions for seven months and then analyzed again. The results of the analysis are presented in this chapter.

### 4.1.1 Effect of processing methods on proximate composition of shea kernel at zero month storage

The proximate composition of shea kernels samples (parboiling and non-parboiling) before storage are presented in Table 4.1. The statistical analysis of the data indicated that there were significant differences ($p<0.05$) between the carbohydrate, crude protein and ash contents of the parboiled and non-parboiled shea Kernels. The parboiled shea kernel had a lower ash content (1.45%) than non-parboiled kernel ash content of (1.88%). Higher carbohydrate content (28.97%) and crude protein (9.85%) were recorded in parboiled kernels as compared to non-parboiled kernels with carbohydrate and crude protein contents of 25.31% and 9.34%, respectively. Fat, nitrogen free extract, crude protein, moisture and energy contents were not significantly different between the parboiled and non-parboiled kernels at $p=0.05$.

Table 4.1: Parboiled and Non-parboiled shea kernel proximate composition at zero month storage

| Source of variation | Fat (%) | Nitrogen free extract (%) | Carbohydrate (%) | Moisture content (%) | Crude protein (%) | Energy Kcal/100g | Crude fibre (%) | Ash (%) |
|---|---|---|---|---|---|---|---|---|
| Parboiled | $52.47_a$ | $27.38_a$ | $28.97_a$ | $7.00_a$ | $9.85_a$ | $623.43_a$ | $1.96_a$ | $1.45_b$ |
| Non-parboiled | $54.92_a$ | $23.54_a$ | $25.31_b$ | $7.20_a$ | $9.34_b$ | $626.47_a$ | $1.93_a$ | $1.88_a$ |
| p. value | 0.20 | 0.32 | 0.02 | 0.90 | 0.03 | 0.83 | 0.62 | 0.04 |

*Values in columns with similar subscript are not significantly different whiles values with different subscripts are significantly different ($p<0.05$)*

Parboiled kernel nitrogen free extract content of 27.38% was not significantly different ($p>0.05$) from the non-parboiled kernel nitrogen free extracts content of 23.54% (Table 4.1). Similarly, no significant difference ($p>0.05$) was found between parboiled kernel crude fibre content of 1.96% and the non-parboiled kernel crude fibre content of 1.93%.

### 4.1.2 Effect of different storage periods of kernel on proximate composition

Investigation into the changes in proximate composition of shea kernel samples between the period of zero and seven months of kernel storage revealed that shea kernels generally increased

in carbohydrate, crude fibre and ash contents while fat, crude protein and energy contents reduced significantly ($p<0.01$) (Table 4.2) .

Table 4.2 Effect of periods of kernel storage on proximate content

| Period of storage | Fat % | Nitrogen free extract % | Carbohydrate % | Moisture content % | Crude protein % | Energy Kcal/100g % | Crude fibre % | Ash % |
|---|---|---|---|---|---|---|---|---|
| Zero month | $53.49_a$ | $26.1_a$ | $27.89_b$ | $7.06_a$ | $9.67_a$ | $625.00_a$ | $1.94_b$ | $1.66_b$ |
| Seven months | $45.22_b$ | $27.92_a$ | $36.03_a$ | $7.64_a$ | $8.1_b$ | $551.00_b$ | $8.51_a$ | $2.82_a$ |
| P.value | 0.00 | 0.06 | 0.00 | 0.43 | 0.00 | 0.00 | 0.00 | 0.00 |

*Values in columns with similar subscript are not significantly different whiles values with different subscripts are significantly different ($p<0.05$)*

Carbohydrate content increased by 29.19%, ash and crude fibre contents by 69.88% and 338.66%, respectively (Table 4.2). Nitrogen free extract and moisture contents did not change significantly. Kernel fat, crude protein and energy contents generally decreased significantly ($p<0.05$) after seven months kernel storage. Kernel decreased in fat content by 15.46%, crude protein

### 4.2.1 Effect of different storage containers of kernel on the proximate composition at seven (7) months storage

Results presented in Table 4.3 shows the effect of the five different kernel storage containers on the proximate composition of kernel after storage. It was revealed that fat, nitrogen free extract,carbohydrate, crude protein, crude fibre, ash and energy contents of kernel samples from the five different storage containers were not significantly different ($p>0.05$). However, significant differences ($p<0.05$) were observed in proximate parameters measured between the two different periods of kernel storage in different containers (Table 4.3).

Table 4.3: Effect of different shea kernel storage containers on the proximate composition after seven (7) months storage period

| Parameter | Kernel proximate content before storage | Kernel proximate content after storage | | | | | |
|---|---|---|---|---|---|---|---|
| | | Cardboard | Synthetic fibre | Jute sack | Plastic bucket | Polyethylene bag | p.value |
| Fat (%) | 54.10a | $45.28_{b}$ | $44.46_{b}$ | $45.12_{b}$ | $46.54_{b}$ | $43.80_{b}$ | 0.00 |
| Nitrogen free extracts (%) | 26.11b | $27.68_{a}$ | $27.68_{a}$ | $28.02_{a}$ | 28.73a | $27.50_{a}$ | 0.03 |
| Carbohydrate (%) | 26.53b | $35.83_{a}$ | $35.96_{a}$ | $36.32_{a}$ | $35.99_{a}$ | $36.05_{a}$ | 0.00 |
| Crude protein (%) | 9.72a | $8.15_{b}$ | $8.28_{b}$ | $8.30_{b}$ | $7.26_{b}$ | $8.55_{b}$ | 0.00 |
| Crude fibre (%) | 1.95b | $9.12_{a}$ | $8.79_{a}$ | $8.14_{a}$ | $8.20_{a}$ | $8.28_{a}$ | 0.00 |
| Ash (%) | 1.66b | $3.01_{a}$ | $2.94_{a}$ | $2.84_{a}$ | $2.61_{a}$ | $2.71_{a}$ | 0.00 |
| Moisture content (%) | 7.1ab | $6.77_{b}$ | $7.87_{ab}$ | $7.60_{ab}$ | $6.84_{ab}$ | $9.17_{a}$ | 0.00 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Energy Kcal/100g | 624.95a | 554.66$_b$ | 545.96$_b$ | 550.71$_b$ | 566.53$_b$ | 537.32$_b$ | 0.00 |

*Values in rows with similar subscript are not significantly different whiles values with different subscripts are significantly different ($p<0.05$).*

The fat content decreased after storage from 54.11% to: 46.54% in kernels kept in the plastic bucket, cardboard (45.28%, jute sack (45.12%), synthetic fibre (44.46%) and polythene bag (43.80%) (table 4.3). Nitrogen free extracts content increased in all the storage containers from 26.11% to 28.73%, 28.02, 27.68%, 27.68%, 27.50%, in shea kernel kept in plastic bucket, jute sack, cardboard, synthetic fibre and polythene bag, respectively. The study also revealed that, carbohydrate content increased from 26.53% to 36.32 in kernels kept in Jute sack, polythene bag (36.05%), plastic bucket (35.99%), synthetic fibre (35.96%), and cardboard (35.83%). Kernels stored in each of the storage containers, increased in crude fibre content about eight folds. Similarly, ash content in kernels increased significantly ($p<0.05$) in all the storage containers (Table 4.3).

The analyses further revealed that shea crude protein content of kernel reduced from 9.72% to: 8.55% in polythene bag, jute sack (8.30%), cardboard (8.15%), synthetic fibre (8.28%) and Plastic bucket (7.26%). Energy content of kernels reduced significantly in all the storage containers.

Shea kernel moisture content (MC) was found to be significantly ($p<0.05$) higher in kernels kept in polythene bag (9.16%) than in cardboard (6.77%). No significant difference ($p>0.01$) was found in kernel moisture content among the other storage containers and kernel moisture before storage (Table 4.3).

### 4.2.2 Interactive effect of processing methods of shea nut and kernel storage containers on proximate composition at seven (7) months storage

The study revealed that the non-parboiled kernel which was kept in the polythene bag had carbohydrate content significantly ($p<0.05$) lower than kernels from parboiled and stored in the other containers and non-parboiled kernels stored in the cardboard (Table 4.4).



Table.4.4: Interactive effect of storage containers and processing methods of shea nuts on proximate composition of kernel after storage

| Interaction between storage containers and processing methods | Fat (%) | Nitrogen free extracts (%) | Carbohydrate (%) | Crude protein (%) | Crude fibre (%) | Ash (%) | Moisture content (%) | Energy (Kcal/100 g) |
|---|---|---|---|---|---|---|---|---|
| Jute sack *Non-parboiled | $47.04_{a}$ | $25.39_{a}$ | $32.67_{ab}$ | $7.28_{a}$ | $8.17_{a}$ | $2.76_{a}$ | $9.36_{ab}$ | $557.7_{a}$ |
| Plastic bucket*Non-parboiled | $46.80_{a}$ | $27.28_{a}$ | $33.92_{ab}$ | $6.64_{a}$ | $8.10_{a}$ | $2.85_{a}$ | $8.34_{abc}$ | $562.7_{a}$ |
| Synthetic fibre*Non- Parboiled | $45.47_{a}$ | $26.28_{a}$ | $33.62_{ab}$ | $7.34_{a}$ | $8.10_{a}$ | $3.09_{a}$ | $9.73_{ab}$ | $545.20_{a}$ |
| Cardboard*Non-parboiled | $45.12_{a}$ | $28.49_{a}$ | $36.08_{a}$ | $7.6_{a}$ | $8.39_{a}$ | $3.01_{a}$ | $7.4b_{c}$ | $553.5_{a}$ |
| Polyethylene bag*Non-Parboiled | $45.11_{a}$ | $25.18_{b}$ | $32.63_{b}$ | $9.64_{a}$ | $7.95_{a}$ | $2.89_{a}$ | $11.42_{a}$ | $538.50_{a}$ |
| Plastic bucket*Parboiled | $46.27_{a}$ | $30.18_{a}$ | $38.03_{a}$ | $7.82_{a}$ | $8.30_{a}$ | $2.37_{a}$ | $5.33_{c}$ | $570.4_{a}$ |
| Cardboard*parboiled | $45.44_{a}$ | $26.87_{a}$ | $35.57_{a}$ | $8.1_{a}$ | $9.84_{a}$ | $3.01_{a}$ | $6.14_{bc}$ | $555.8_{a}$ |
| Synthetic *parboiled | $43.44_{a}$ | $29.10_{a}$ | $38.30_{a}$ | $9.21_{a}$ | $9.48_{a}$ | $2.78_{a}$ | $6.00_{bc}$ | $546.70_{a}$ |
| Jute sack *Parboiled | $43.2_{a}$ | $30.65_{a}$ | $39.96_{a}$ | $9.31_{a}$ | $8.10_{a}$ | $2.92_{a}$ | $5.84_{bc}$ | $543.7_{a}$ |
| Polyethylene bag*Parboiled | $42.49_{a}$ | $29.83_{a}$ | $39.47_{a}$ | $7.45_{a}$ | $8.61_{a}$ | $2.53_{a}$ | $6.91_{bc}$ | $536.20_{a}$ |
| p.value | 1.9 | 4.6 | 4.5 | 9.5 | 5.9 | 4.5 | 6.9 | 1.3 |

*Values in columns with similar subscript are not significantly different whiles values with different subscripts are significantly different ($p<0.05$)*

Non-parboiled kernels stored in polyethylene bag were significantly higher in moisture content than non-parboiled kernel kept in cardboard and parboiled kernels kept in other containers including the cardboard. Again, non-parboiled kernels stored in jute sack and synthetic fibre was significantly higher in moisture content than parboiled kernels stored in the other containers. No significant interactive effect were found among the storage containers and kernel processing method in crude protein, crude fibre, ash and energy contents of the kernels after seven (7) months storage period (Table 4.4).

### 4.3 Assessment of fungi infection

Table 4.5 shows the fungi identified and percent infection on shea kernels samples. There was no significant difference ($p>0.05$) between the two different processing methods of shea kernels.

The percentage of *Aspergillus niger* content in the shea kernels were the similar.

Table 4.5: Identification and percent infection of Fungi on parboiled and non-parboiled shea kernels at zero and seven months kernel storage

| | Fungi identified | | Fungi infection (%) | |
|---|---|---|---|---|
| source of variation | Before storage | After storage | Before Storage | After storage |
| Parboiled kernel | *A.niger* | *A.niger* | $2.33_a$ | $2.40_a$ |
| Non-parboiled kernel | *A.niger* | *A.niger* | $2.30_a$ | $2.30_a$ |

*Values in columns with similar subscript are not significantly different whiles values with different subscripts are significantly different ($p<0.05$)*

### 4.4 Effect of different processing methods of shea nut and kernel storage containers on free fatty acids profile and peroxide value of extracted butter

#### 4.4.1 Effect of different processing methods of nut on free fatty acids (FFA) profile and peroxide value (PV) of the extracted butter at zero month kernel storage.

Table 4.6 shows that free fatty acids and peroxide values of the extracted shea butter from parboiled and non-parboiled kernels were significantly different ($p<0.05$). The free fatty acids profile values were significantly higher in shea butter derived from non-parboiled kernels than the parboiled.

Table 4.6 Effect of Parboiled and Non-parboiled shea nuts on shea butter free fatty acid profile and peroxide value at zero month kernel storage

| Source of Variation | Oleic (%) | Linoleic (%) | Linolenic (%) | Palmitic (%) | Stearic (%) | Peroxide value (%) |
|---|---|---|---|---|---|---|
| Parboiled kernel | $1.13_b$ | $2.60_b$ | $2.59_b$ | $2.38_b$ | $1.71_b$ | $8.34_b$ |
| Non-parboiled kernel | $6.49_a$ | $17.61_a$ | $17.50_a$ | $16.10_a$ | $11.6_a$ | $5.50_a$ |
| p.value | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.02 |

*Values in columns with similar subscript are not significantly different whiles values with different subscripts are significantly different ($p<0.05$)*

The result further revealed that shea butter derived from parboiled kernel had higher ($p<0.05$) peroxide value than non-parboiled kernel (Table 4.6).

### 4.4.2 Effect of different periods of storage of kernel on free fatty acid profile and peroxide value of extracted shea butter

Results in Table 4.7 revealed free fatty acid and peroxide value characteristics of the extracted butter from shea kernel samples at different storage periods. There were significant differences ($p<0.05$) in shea butter oleic acid and peroxide value between zero month and seven months storage of shea kernel samples. The oleic acid content of the kernel increased while the peroxide value decreased significantly.

Table 4.7:Effect of different periods of kernel storage on free fatty acids profile and peroxide value characteristics

| Period of storage | Oleic% | Linoleic% | Linolenic% | Palmitic% | Stearic% | peroxide value% |
|---|---|---|---|---|---|---|
| Zero month | $3.8\pm0.85_b$ | $10.11\pm2.37_a$ | $10.04\pm2.36_a$ | $9.24\pm2.17_a$ | $6.65\pm1.56_a$ | $6.92\pm0.45_a$ |
| Seven months | $7.02\pm0.03_a$ | $7.11\pm0.19_a$ | $7.07\pm0.19_a$ | $6.46\pm0.18_a$ | $4.67\pm0.13_a$ | $3.69\pm0.07_a$ |
| p.value | 0.02 | 0.28 | 0.28 | 0.27 | 0.28 | 0.00 |

*Values in columns with similar subscript are not significantly different whiles values with different subscripts are significantly different ($p<0.05$)*

The linoleic, linolenic, palmitic and stearic acids contents of the kernel samples did not significantly ($p>0.05$) change after seven months storage period. Generally, there was a decreased in their contents.

### 4.4.3 Effect of different storage containers of kernel on free fatty acid profile and peroxide value of extracted shea butter

It can be observed from Table 4.8 that there were no significant differences ($p>0.05$) in free fatty acids components in shea butter produced from the different storage containers. However, significant ($p<0.05$) increase in oleic content of shea kernel was observed in all the storage containers except those kept in plastic bucket after seven months storage. Similarly, palmitic, stearic, linoleic and linolenic contents of kernel did not change significantly in all the storage containers except those kept in plastic bucket (Table 4.8).

Table 4.8: Effect of different storage containers of kernel on the free fatty acid profile and peroxide value characteristics of butter

| Parameter | FFA&PV of kernels before storage | FFA&PV of kernels after storage | | | | | |
|---|---|---|---|---|---|---|---|
| | | Card board | Synthetic fibre | Jute sack | Plastic bucket | Polyethylene bag | p.value |
| Oleic (%) | $3.81_{b}$ | $7.75_{a}$ | $7.05_{a}$ | $7.06_{a}$ | $6.91_{ab}$ | $7.08_{a}$ | 0.00 |
| Palmitic (%) | $9.24_{a}$ | $6.97_{ab}$ | $6.69_{ab}$ | $6.25_{b}$ | $5.93_{b}$ | $6.43_{ab}$ | 0.03 |
| Stearic (%) | $6.65_{a}$ | $5.01_{ab}$ | $4.84_{ab}$ | $4.65_{ab}$ | $4.25_{b}$ | $4.62_{ab}$ | 0.01 |
| Linoleic (%) | $10.11_{a}$ | $7.63_{a}$ | $7.37_{a}$ | $7.08_{a}$ | $6.48_{b}$ | $7.03_{a}$ | 0.01 |
| Linolenic (%) | $10.05_{a}$ | $7.57_{a}$ | $7.32_{a}$ | $7.03_{a}$ | $6.44_{b}$ | $6.98_{a}$ | 0.01 |
| Peroxide value (%) | $6.92_{a}$ | $3.43_{b}$ | $3.70_{b}$ | $3.85_{b}$ | $3.68_{b}$ | $3.77_{b}$ | 0.00 |

*Values in row with similar subscript are not significantly different whiles values with different subscripts are significantly different ($p<0.05$)*

Shea kernels peroxide value reduced significantly ($p<0.05$) in all the storage containers but no significant differences ($p>0.05$) after seven months storage but no significant differences ($p>0.05$) were found among the storage containers (Table 4.8).



### 4.4.4 Interactive effect of shea nut processing methods and kernel storage containers on the free fatty acid profile and peroxide value characteristics of butter produced

Shea kernel which was not parboiled and stored in polythene bag resulted in high values of free fatty acid profile contents of the butter produced (Table 4.9). The results obtained, indicated that

butter from the different shea kernel source and stored in each of the five different materials were significantly different ($p<0.05$) from each other.

Table.4.9: Interactive effect of kernel storage container and shea nut processing methods on the free fatty acids profile and peroxide value of butter produced

| Interaction between storage containers and processing methods | Oleic (%) | Palmitic (%) | Stearic (%) | Linoleic (%) | Linolenic (%) | Peroxide value (%) |
|---|---|---|---|---|---|---|
| Polyethylene bag *Non-parboiled | $11.66_{a}$ | $10.58_{a}$ | $7.60_{a}$ | $11.57_{a}$ | $11.49_{a}$ | $2.72_{b}$ |
| Jute sack *Non-parboiled | $11.21_{a}$ | $10.17_{a}$ | $7.31_{a}$ | $11.13_{a}$ | $11.04_{a}$ | $3.28_{b}$ |
| Card board *Non-parboiled | $10.95_{a}$ | $9.94_{a}$ | $7.14_{a}$ | $10.87_{a}$ | $10.79_{a}$ | $2.84_{b}$ |
| Plastic bucket *Non-parboiled | $10.85_{a}$ | $9.85_{a}$ | $7.05_{a}$ | $10.78_{a}$ | $10.70_{a}$ | $2.89_{b}$ |
| Synthetic *Non-parboiled | $10.72_{a}$ | $9.64_{a}$ | $6.99_{a}$ | $10.64^{a}$ | $10.56_{a}$ | $3.14_{b}$ |
| Cardboard * Parboiled | $4.56_{b}$ | $4.01_{b}$ | $2.88_{b}$ | $4.38_{b}$ | $4.35_{b}$ | $4.03_{a}$ |
| Synthetic fibre *Parboiled | $3.38_{b}$ | $3.75_{bc}$ | $2.69_{bc}$ | $4.11_{bc}$ | $4.07_{bc}$ | $4.56_{a}$ |
| Plastic bucket* Parboiled | $2.96_{b}$ | $2.00_{c}$ | $1.44_{c}$ | $2.49_{c}$ | $2.18_{c}$ | $4.50_{a}$ |
| Jute sack *Parboiled | $2.91_{b}$ | $2.32_{bc}$ | $1.99_{bc}$ | $3.03_{bc}$ | $3.01_{bc}$ | $4.25_{a}$ |
| Polyethylene bag *Parboiled | $2.51_{b}$ | $2.28_{bc}$ | $1.64_{bc}$ | $2.19_{bc}$ | $2.48_{bc}$ | $4.61_{a}$ |
| CV (%) | 2.5 | 1.6 | 2.6 | 2.5 | 2.5 | 6.8 |

*Values in columns with similar subscript are not significantly different whiles values with different subscripts are significantly different ($p<0.05$)*

Butter obtained from shea kernel, which was parboiled, and kept in cardboard, synthetic fibre and jute sack were not significantly different from each other with respect to all the parameters determined. In addition, shea kernel, which was not parboiled and stored in Jute sack, synthetic fibre and cardboard, were not significantly different in terms of the parameters determined on the butter produced. It was observed from the results that non-parboiled kernel stored in polythene bag had the highest values in

the free fatty acids components and parboiled kernel stored in plastic bucket recorded lowest values in all the free fatty acids component except oleic and linoleic which were lowest in butter obtained from parboiled kernel stored in polythene bag.



**4.4.5 Effect of shea nut processing methods on sensorial quality characteristics of butter produced.**

Regarding the sensory characteristics of shea butter descriptive analysis performed on the responses given by individuals showed variation in color, aroma and taste of butter extracted from parboiled and non-parboiled sources of shea kernels (Table 4.10).

Table: 4.10: The effect of different processing methods of shea nut on the sensorial quality characteristics of butter produced

| Source of Variation | Appearance | Nutty smell score (%) | | | | Bitter taste score (%) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | colour | No Smell | Mild | Intense | Very Intense | No bitterness | Mild | Strong | very strong |
| Parboiled | Beige | 0 | 0 | 100 | 0 | 100 | 0 | 0 | 0 |
| Non-parboiled | Ivory | 20 | 80 | 0 | 0 | 0 | 100 | 0 | 0 |

Shea butter extracted from parboiled and non-parboiled kernels, exhibited aroma (nutty smell) differently from each other. The parboiled kernel butter tends to have nutty smell than the nonparboiled kernel butter. Table 4.10 shows the scoring of each sensorial parameter by five panelists. The score was 100% nutty smell for parboiled kernel source of butter while 80% was scored for mild and 20% no nutty smell for the non-parboiled kernel source of butter. Descriptive respondent for taste scored parboiled kernel source of butter to have 100% no bitter taste while the

non-parboiled scored 100% mild bitter taste. When shea butter samples were matched with the colour chart sheet (Appendix D, plate 7) the colours identified were beige and ivory for the parboiled and non-parboiled kernel butter, respectively.

### 4.5 Correlation analysis on the parameters measured

Results from the analysis of correlation between the various parameters measured indicates significantly (P<0.01) positive relationship between energy and fat, nitrogen free extracts and carbohydrate while fat and carbohydrate from both kernels sources (parboiled and non- parboiled) shows significantly negative relationship (Tables 4. 11&12).

Table 4.11: Correlation between parboiled kernel proximate composition and environmental factors

| | %Ash | %CHO | %Fat | %MC | %NFE | %Protein | %Fibre | %Kcal/100g | %RH | TºC |
|---|---|---|---|---|---|---|---|---|---|---|
| %Ash | | | | | | | | | | |
| %CHO | 0.08 | | | | | | | | | |
| %Fat | -0.20 | -0.91** | | | | | | | | |
| %MC | 0.55* | -0.05 | 0.01 | | | | | | | |
| %NFE | 0.08 | 0.97** | -0.86** | -0.03 | | | | | | |
| %Protein | 0.04 | 0.48 | -0.50 | -0.09 | 0.25 | | | | | |
| %Fibre | -0.09 | -0.41 | 0.08 | 0.09 | -0.42 | -0.11 | | | | |
| %Kcal/100g | -0.27 | -0.83** | 0.97** | 0.02 | -0.74** | -0.63* | 0.05 | | | |
| RH% | -0.45 | -0.08 | 0.04 | -0.32 | -0.12 | 0.14 | 0.03 | -0.02 | | |
| TºC | -0.02 | 0.36 | -0.20 | -0.02 | 0.24 | 0.55* | -0.46* | -0.24 | 0.29 | - |

**Correlation is significant at 5% level; ** Correlation is significant at 1% levels*

**Note:** CHO=carbohydrate, MC=moisture content, NFE=Nitrogen free extract, TºC.=Temperature

Also energy and nitrogen free extracts, protein and energy, fat and nitrogen free extracts, carbohydrate and energy, were observed to be significantly negatively related with the parboiled kernels (Table 4.11) whereas crude fibre and carbohydrate, nitrogen free extracts and crude fibre, energy and protein, fat and protein were found with the non-parboiled kernels to show significant negative relationship (Table 4.12). There was positive relationship between crude fibre and ash content in non-parboiled kernels.

Table .4:12 Correlations between non-parboiled kernel proximate composition and environmental factors.

| | %Ash | %CHO | %Fat | %MC | %NFE | %Protein | %Fibre | %Kcal/100g | RH% | TºC |
|---|---|---|---|---|---|---|---|---|---|---|
| %Ash | - | | | | | | | | | |
| %CHO | -0.21 | - | | | | | | | | |
| %Fat | -0.03 | 0.78** | | | | | | | | |
| %MC | 0.05 | 0.16 | -0.02 | | | | | | | |
| %NFE | -0.25 | 0.97** | -0.69* | 0.14 | | | | | | |
| %Protein | 0.08 | 0.30 | -0.52* | 0.08 | 0.06 | | | | | |
| %Fibre | 0.44* | -0.59* | 0.28 | 0.11 | -0.66* | 0.17 | | | | |
| %KCAL_100g | -0.17 | -0.38 | 0.86** | 0.13 | -0.23 | -0.64* | 0.03 | | | |
| RH% | -0.20 | -0.32 | 0.13 | -0.12 | -0.34 | 0.00 | 0.06 | -0.11 | | |
| TºC | 0.11 | 0.06 | -0.08 | -0.29 | -0.01 | 0.30 | -0.07 | -0.14 | -0.30 | - |

**Correlation is significant at 5% level; ** Correlation is significant at 1% level*

**Note:** CHO=carbohydrate, MC=moisture content, NFE=Nitrogen free extract, TºC.=Temperature

Furthermore, it was revealed that temperature has significant (P<0.05) positive influence on parboiled kernel crude protein content but rather influences the crude fibre content negatively.

Moisture was also observed to significantly (P<0.05) and positively influence ash content in the. kernel (Table 4.11&4.12). No significant relationship was found among the other parameters on kernel proximate composition

Table 4.13: Correlation between parboiled shea kernel butter free fatty acid profile, peroxide value & environmental factors

| | Stearic | Linolenic | Linoleic | T°C | RH% | Palmitic | PV | Oleic | %MC |
|---|---|---|---|---|---|---|---|---|---|
| Stearic | - | | | | | | | | |
| Linolenic | 1** | | | | | | | | |
| Linoleic | 1** | 1** | | | | | | | |
| T°C | -0.03 | -0.03 | -0.03 | | | | | | |
| RH% | -0.00 | -0.00 | -0.00 | 0.29 | | | | | |
| Palmitic | 0.95** | 0.95** | 0.95** | -0.12 | -0.08 | | | | |
| PV | -0.42* | -0.42* | -0.42* | 0.10 | 0.01 | -0.26 | | | |
| Oleic | 0.75** | 0.75** | 0.75** | -0.11 | 0.03 | 0.71** | -0.25 | | |
| %MC | 0.55** | 0.54** | 0.55* | -0.02 | -0.32 | 0.46* | -0.22 | 0.34 | - |

**Correlation is significant at 5% level; ** Correlation is significant at 1% level*

**Note:** PV=Peroxide value, T$^{O}$C=Temperature, RH =Relative humidity, MC= Moisture content

Results presented in tables 4.13 and 4.14 show that moisture has significantly (p<0.01) positive linkage with the free fatty acids constituents‟ of the parboiled kernels while temperature has

positive relationship with peroxide value of the non-parboiled kernels. Similarly, there was significant positive correlation between the following: stearic, linolenic, linoleic oleic and palmitic in both parboiled and non-parboild kernels. The peroxide value (PV) was observed to influence negatively stearic, linolenic and linoleic contents significantly in the parboiled kernel (Table 4.14)

It was observed that temperature relate with peroxide value positively in the non-parboiled kernel (Table 4.14) but very weak with peroxide value in the parboiled kernel (Table 4.13).

Table 4.14: Correlation between Non-parboiled shea kernel butter FFA profile ,PV and Environmental factors

| | Stearic | Linolenic | Linoleic | T°C | RH% | Palmitic | PV | Oleic | %MC |
|---|---|---|---|---|---|---|---|---|---|
| Stearic | | | | | | | | | |
| Linolenic | 1** | | | | | | | | |
| Linoleic | 1** | 1** | | | | | | | |
| T°C | 0.03 | 0.02 | 0.3 | | | | | | |
| RH% | 0.28 | 0.28 | 0.28 | -0.3 | | | | | |
| Palmitic | 0.99** | 0.99** | 0.99** | 0.02 | 0.27 | | | | |
| PV | 0.19 | 0.19 | 0.18 | 0.54* | 0.04 | 0.18 | | | |
| Oleic | 1** | 1** | 1** | 0.03 | 0.28 | 0.99 | 0.18 | | |
| %MC | 0.29 | 0.3 | 0.3 | -0.29 | 0.12 | 0.32 | 0.19 | -0.3 | - |

**Correlation is significant at 5% level; ** Correlation is significant at 1% level*

## 4.6 Temperature and relative humidity Variations in storage containers during kernel storage period.

Temperature and relative humidity inside the kernel storage containers were considered and the results indicated that temperature readings (°C) inside the different storage containers did not varied significantly ($p>0.05$) while relative humidity percentages was significantly ($p<0.05$) higher in jute sack and polyethylene bag than what was recorded in the cardboard container (Table 4.15).

Table 4.15: Monthly mean temperature and relative humidity inside storage containers

| Storage container | Temperature (°C) | Relative Humidity (%) |
|---|---|---|
| Cardboard | $26.10_a$ | $74.58_b$ |
| Plastic bucket | $26.00_a$ | $76.72_{ab}$ |
| Synthetic fibre | $26.07_a$ | $76.5_{ab}$ |
| Polyethylene bag | $26.22_a$ | $77.68_a$ |
| Jute sack | $25.93_a$ | $78.27_a$ |
| p.value | 0.96 | 0.01 |

*Values in columns with similar subscript are not significantly different whiles values with different subscripts are significantly different ($p<0.05$)*

The mean relative humidity outside the storage room at CRIG substation, Bole during the storage period was between 53.28% and 70.53% much lesser than the relative humidity ranges from 74.58% to 78.27% inside storage containers (Appendix A, Table 1 and Table 4.15).

Temperature outside the storage room was between 20.94 $^{o}$C and 32.24 $^{o}$C while inside the storage containers ranges between 25.93$^{o}$C to 26.22$^{o}$C (Appendix A table 1 and Table 4.15).



# CHAPTER FIVE

## 5.0 DISCUSION

The overall value of shea nuts industry lies in the individual value of the various chains of production. The production and processing of quality shea kernel and butter to meet the increasing demand locally and internationally, is a big challenge to a Ghanaian shea nut producer.

According to report by Ferris *et al*., (2001), Cooperative Office for Voluntary Organization in Uganda (COVOL) has introduced a strong campaign to improve nut quality. Many authors linked quality shea kernel and extracted butter with processing and storage factors (Kiyayila, 2002; Megnanou *et al*., 2007; Kapseu *et al* 2007). Anchirinah *et al*. (2012) and Obibuzor *et al*. (2013) reported that, processing methods, kernel storage and phytosanitory conditions are some of the major challenges leading to production of low quality shea butter.

The present study evaluated the primary processing methods of the fresh shea nuts (parboiling and non-parboiling), different storage containers and periods of kernel on some quality characteristics of the kernel and extracted butter. The result in this present study confirmed that, there were variations between parboiled and non-parboiled shea kernel proximate composition and physico-chemical characteristics of the extracted butter.

The five different kernel storage containers evaluated for their influence on the proximate constituents at seven months storage indicated that there was no significant differences ($p>0.01$) in kernel samples proximate composition except the moisture content.

The analysis also showed that different periods of kernel storage significantly ($p<0.05$) affected proximate composition of the kernel.

### 5.1.1 Effect of shea nut processing methods on kernel proximate characteristics

Shea kernel carbohydrate, crude protein and ash contents were significantly ($p<0.05$) affected by shea nut processing methods. The parboiled shea kernel had significantly lower ash content (1.45%) but higher carbohydrate (28.97%) and crude protein (9.85%) than the non-parboiled shea kernel of 1.88%, 25.31% and 9.34% respectively.

Tano-Debrah and Ohta, (2004) reported that shea kernel has carbohydrate content of 34.77% which in comparison with the present observation is relatively higher than both parboiled and non-parboiled shea kernel carbohydrate of 28.97% and 25.31% respectively. However, it is important to note that shea kernels when kept for a minimum period of seven months has the possibility of increasing carbohydrate content by 29.18% as illustrated in the present study (4.2). The relatively lower carbohydrate content in shea kernels, which was processed at zero month storage after harvesting in the present study, compared to what has been reported by Tano-Derah and Ohta (2004) could be attributed to differences in kernel storage period before processing though the previous reporters did not indicate how long the kernels were kept before processing. Carbohydrates are vital in nutrition because they are source of energy (Anhwange *et al*., 2004) and therefore its availability in shea kernel is important for food preparation and livestock feed

formulation. Pearson (1991) reported that carbohydrate content in fruits which ranges between 40-60% are good for both human and livestock consumption. The processing methods of fresh shea nuts significantly influenced higher percentage of carbohydrate in parboiled kernels than in non-parboiled kernels. In comparison to shea fruit pulp carbohydrate content of 64.25% reported by (Omujal, 2009), the shea kernel is relatively lower in carbohydrate content notwithstanding, the values of 28.97% and 25.31% is good enough to be considered as energy source food.

The present study also revealed that shea kernel crude protein content was significantly ($p<0.05$) higher in parboiled kernel (9.85%) than the non-parboiled kernel (9.34%). The variation in crude protein content between parboiled and non-parboiled kernels may be associated with proteolytic enzymes activities which were possibly been secreted from living embryo of non-parboiled kernels thereby causing the decrease in protein content considering the reports by Omujal (2009) that proteolytic enzymes when produced in the kernel are capable of reducing protein content. The lower crude protein in non-parboiled shea kernels and the higher percent reduction during kernel storage than the parboiled shea kernels could be link to higher increase in moisture content in the non-parboiled kernels. Higher moisture content in kernels will render the protein more available for degradative attack through the creation of more surface area for the activity of microorganism (Mojisola and Bankefa, 2014).

It has been reported that parboiling kills the embryo in the kernel which secrets the lipase enzymes responsible for protein degradation (Aculey et al., 2012), which implies that the higher crude protein content observed in parboiled kernels could also be due to positive correlation between temperature and crude protein content of the kernel (Table 4.11). Therefore, in order to obtain higher crude protein content of the kernel, parboiling processing could be the choice. It is important

to note that protein plays a very important role in nutrition by catalyzing, regulating, protecting and providing energy (Haverkot and Hiemstra, 1999) and therefore it availability in the kernel is vital.

The nitrogen free extracts content of 27.38% was recorded in the parboiled shea kernel as compare to non-parboiled kernel content of 23.54%/. Tables 4.11 & 4.12 shows that nitrogen free extracts had negative statistical linkage with fat and since parboiled kernels recorded relatively lesser fat content than non-parboiled kernels, one could anticipate nitrogen content from the non-parboiled kernels to be relatively lower than the parboiled because there could be compensatory response. Nitrogen-free extract (NFE) represents the non-structural carbohydrates such as starches and sugars that could easily be influenced by heat (parboiling) and probably increases its content. According to Ugese *et al*. (2010), not much seems to be known about the proximate chemical constitution of the shea kernel as a whole. Nitrogen free extracts component of the shea kernel seems to be the first time it is determined. There is therefore, a need to investigate more about the shea kernel nitrogen free extracts.

Ash content of the kernel samples was significantly ($p<0.05$) higher in non-parboiled kernels than in parboiled kernels. Ash content is a measure of the total minerals present in the kernel (McClements, 2005), which suggests that the non-parboiled kernel may have more mineral content than the parboiled kernel. The ash content of 1.45% and 1.88% in parboiled and nonparboiled kernels, respectively were relatively lower than ash content of the shea fruit reported by (Omujal, 2009) to range between 3.61% and 5.90%. All these observations are confirming the finding by

Bernice, (2011) that the shea tree and its products provides nutritional and economic benefits of many people especially, rural folks.

The calorific value (energy) content in the non-parboiled kernel was 626.47 Kcal/100g as compared to the parboiled kernel 623.43Kcal/100g. Although there was no significant difference ($p>0.05$) between the parboiled and non-parboiled kernel energy content, it is important to note that energy content had significant ($p<0.01$) negative statistical linkage with carbohydrate and crude protein but positively correlated with fat and ash and therefore, was relatively low in parboiled kernel than in non-parboiled. This observation confirmed Ugese *et al* (2010) that ash and carbohydrate are negatively correlated (Tables 4.11 and 4.12) and hence any practice that will enhance carbohydrate content of the shea kernel could result to lowering of the ash content.

The fat content from both parboiled and non-parboiled kernels was comparatively impressive when rated with fat ranges of 30.2-34.8% and 41-53.53% reported by Ugese *et al*. (2010) and OKollu *et al*. (2010) respectively. The non-parboiled kernel had fat content of 54.92% while parboiled kernel had 52.47% in contrast to the values (53.08% and 54.62%) for non-parboiled and parboiled kernels shea butter, respectively reported by Aculey *et al* (2012). Fat content ranges between 45% and 62% from shea nuts obtained from Northern Ghana were reported by (Adu-Ampomah *et al*., 1995). According to Maranz *et al*. (2004) fat content between 20% and 30% are low, but those in the mid 30‟s are intermediate and above 40% are good. In this respect, the fat content (52.47% and 54.92%) from both Parboiled and non-parboiled kernels respectively in the present research could be regarded as good. Ruyssen (1957) observed that there was variation in fat content in nuts from Mali, Benin and Burkina Faso. In Mali, the lower values were obtained from North West: 33.5%-40% fat compared with 45% for the national average. This variation in fat content could be attributed to different shea nuts processing methods, genetic or

environmental factors (Omujal, 2009) . Knowledge gathered from the local shea nut processors who uses traditional aqueous butter /fat extraction method, revealed that more butter is obtained from the parboiled nuts than the non-parboiled nuts (personal interaction with local processors) but in this study there no significant differences ($p<0.05$) between parboiled and nonparboiled kernel. The fat has cosmetic, confectionery and pharmaceutical uses (Kent and Bakaweri, 2010).

The differences in values observed with shea kernel proximate composition between parboiled and non-parboiled in this study confirmed the presumption made by Nahm (2011) that fresh shea nut treatment among others could be an underlying cause in differences in the quality characteristic of shea butter from different places.

The present study which recorded: carbohydrate 28.97% and 25.31%; crude protein 9.85% and 9.34%; ash 1.88% and 1.45%; fat 52.47% and 54.92%; crude fibre 1.96% and1.93%; moisture content 7.06% and 7.20%; energy 623.43% and 626.47% for parboiled and non-parboiled, respectively were relatively different from values reported by Ugese *et al.* (2010) from Uganda. Carbohydrate content (48.1-44.1%), crude protein content (8.1-7.1), ash content (4.9-4.5%), fat content (34.8-30.1%), crude fibre content (6.8-5.8) and moisture content (3.2-2.7%) in kernels from Ugunda were recorded which suggests that shea kernels from Ghana, especially, when not parboiled contains relatively higher fat content than Uganda shea kernels. Crude protein was also relatively higher in Ghana shea kernel of both parboiled and non-parboiled than those of Uganda. Carbohydrate, crude fibre and ash contents of Uganda shea kernel were comparatively higher than values obtained from parboiled and non-parboiled shea kernels from Ghana. These observations confirmed Ruyssen (1957) that there were variations in fat content in nuts from Mali, Benin and

Burkina Faso. In Mali, the national average fat content was 45% compared to Benin and Burkina Faso with fat content in nuts recording 50% or more. The fat and crude protein values from parboiled and non-parboiled shea kernels obtained in this study were quite impressive as compare to values from Uganda shea nuts reported by (Ugese 2010). The differences between Ghana and Uganda shea kernel proximate contents could be attributed to environmental influence, genetic variation, geographical locations, agronomic factors and postharvest practices (Dei *et al*., 2007; Kapseu *et al*., 2007). The variations observed between parboiled and non-parboiled shea kernels from Ghana, which were picked from the same locality depict that fresh shea nuts processing methods is key factor affecting shea kernel proximate composition and should be considered as quality control factor in shea nut industry.

### 5.1.2 Effect of shea nut processing methods on mouldiness of shea kernel

Mouldiness of kernel was evaluated as quality characteristics of the kernel. Table 4.6 presents results on the identification and colony count of Fungi isolated from Shea Kernel among the two different processing methods of fresh shea nuts (parboiled and non-parboiled). There was no significant different ($p>0.01$) between the shea kernel samples in mould infection. The percentage of *Aspergillus niger* content in the two shea kernel samples was the same at (2.33%). According to Aculey *et al*. (2012), parboiling destroys the shea kernel mechanism providing protection against fungal infection, which results to low quality kernels. In this present study, both parboiled and non-parboiled kernels were dried under similar conditions in solar driers. It was revealed that the effect of fungi on the kernels was not significantly different. The main species of fungi detected was *Aspergillus niger*. The result in this study appears to agree with the report by Aye (1989), that when ripe shea fruits are depulped, washed, blanched and dried using solar drier, the incidence of

fungal growth could be greatly reduced or even prevented. Fungi infection on shea kernels may not simply be facilitated by parboiling of nuts but other factors along each unit operation in the production line.



### 5.1.3 Effect of shea nut processing methods on shea butter quality characteristics

In commercial setting such as manufacturing and trade, evaluation of physico-chemical characteristics of shea butter quality is very significant (Omujal, 2009). Various units of operation in shea nut processing, such as nut collection/harvesting, nut treatment, drying, storage and butter extraction are accountable in determining the physico-chemical characteristics of shea butter (USAID, 2004).

Quality of fats and oils are dictated by several physical and chemical parameters that are dependent on the source of oil; geographic, climatic, and agronomic variables of growth in the case of plant oils as well as processing and storage conditions (Nahm 2011, Hall *et al.,* 1996). From the present study, it was revealed that shea butter extracted from two different processing methods of the fresh shea nut (parboiled and non-parboiled), were significantly different ($p<0.01$) in physico-chemical characteristics as indicated in Tables 4.7 & 4.10.

The statistical analysis revealed that non-parboiled kernels butter had significantly ($p<0.01$) higher free fatty acid profile and lower peroxide value in butter samples compared to parboiled kernels butter. The results in this study confirms reports by (Omajul, 2009; Aculey *et al*., 2012; Megnanou *et al*., 2007) who found that shea butter free fatty acid values were higher but peroxide value lower in parboiled shea nut than non-parboiled. In this study, non-parboiled kernel butter recorded values for oleic (6.49 ± 0.07), linoleic (17.61 ±0.86), linolenic (17.5 ±2.12), palmitic (16.1 ± 0.14), stearic

(11.6 ± 0.68), and peroxide value (5.50 ± 0.7) whereas parboiled kernel butter recorded value as; 1.13 ±0.01, 2.60 ± 0.14, 2.59 ± 0.07, 2.38 ±0.20, 1.71 ± 0.16, 8.34 ± 1.41 for oleic, linoleic, linolenic, palmitic, stearic, and peroxide value, respectively. The free fatty acid (FFA) content and peroxide value (PV) the level of deterioration in an oilseed or oil as a result of the hydrolysis of triglyceride to produce unesterified fatty acids (Nahm, 2011; Aculey *et al*., 2012; Obibuzo et al., 2013; Hall *et al.,* 1996). Quality criteria of shea products based on biological or environmental factors are: fatty acids (mainly stearic, oleic, palmitic linoleic, arachidic acids); unsaponifiable (group of chemicals credited with giving shea butter its therapeutic properties e.g vitamin content, moisturing and conditioning properties- higher levels preferred for cosmetics and pharmaceuticals (Omujal,2009).

The free fatty acid profile of the shea butter determined in this study were; palmitic, stearic, oleic, linoleic and linonelic. Free or unesterified fatty acids are ubiquitous in minor components of all living tissues. They play obvious role as a source of energy and influence the activities of protein kinases, phospholipases, G-proteins, adenylate and guanylate, cyclases and many other metabolic processes. They also influence glucose metabolism, mitigate the undesirable symptoms of the metabolic syndrome and may even reduce the risk of heart disease. In effect, free fatty acids act as nutrient sensors to regulate energy homeostasis (Verlag, 2003). It has been suggested that the stearic acid content has a beneficial effect on total cholesterol, LDL cholesterol and factor VII coagulant activity in human (Tholstrup *et al*., 1994). These two acids were significantly higher with the non-parboiled kernel butter than the parboiled indicating that non-parboiling could improve kernel quality.

There are reports, which indicate that they have potent antimicrobial, antiviral and antifungal properties (Obibuzor *et al*., 2013; Aculey *et al*., 2012). Dogbevi, (2009) reported that essential fatty acids found in shea butter, helps to protect and revitalize damaged skin and hair and it is known to be naturally rich in vitamins A, E, and F, and other vitamins and minerals. Vitamins A and E help to smooth, hydrate, and balance the skin. The kernel itself is rich in vitamin A (Vivien, 1994) which means by avoiding parboiling the vitamin A constituent could be preserved because vitamins are thermal sensitive. However, very high amount of free fatty acids in the shea butter affect the quality of the butter since fatty acids formation is due to the hydrolysis and oxidation of the triacylglcerol in the shea butter and is one of the major constraints the butter processors strive to minimize in order to produce high quality butter (Aculey *et al*. (2012). The result obtained from this study shows that the non-parboiled kernel butter had significant ($p<0.01$) higher free fatty acid profile levels than parboiled shea kernel butter but lower peroxide value which agree with reports by Megnanou *et al*. (2013), Aculey *et al*. (2012), Omajul *et al*. (2009) and Nahm, (2011). Megnanou *et al*. (2007) noted that, the underlining impacts of raw material treatment on products quality are many. Shea butter quality depends on the quality of nuts processing methods and storage factors (Nahm, 2011). To monitor any deterioration of shea butter, kernel processing is very vital as illustrated in this study. It is interesting to note that, the free fatty acids profile and peroxide value from both parboiled and non-parboiled shea kernel butter were within the range reported by other authors (Obibuzor *et al*., 2013; Omujal, 2009; Nahm, 2011; Megnanou and Niamke, 2013; Aculey *et al*., 2012). This implies that both parboiled and non-parboiled shea kernels butter free fatty acids contents could be accepted as normal.

Peroxide value (PV) in shea butter is indicative of degradation, possibly causing malodorous ketones and aldehydes (Perakis, 2009). The use of peroxide value as butter quality indicator is only reliable during the initial stages of lipid oxidation because the peroxide value increases to a maximum and then decreases as

storage time increases (Omujal, 2009. Formation of peroxide is a chemical reaction and like most reactions, it is influence by heat and some other factors (Akinoso *et al.,* 2010) which was confirmed in this work as peroxide value was observed to be higher with the parboiled (heat treated) shea kernel butter than non-parboiled kernel butter (Table 4.6).

Basically, oxidative reaction proceed when oxygen react with the double bonds of unsaturated fatty acids (FFA) and thus oils and fats containing higher levels of unsaturated fatty acids such as shea butter are more susceptible to oxidation (Pokorny *et al*., 2001; Damodaran *et al*., 2008). Megnanou and Niame, (2013) reported that free fatty acids and peroxide levels rises with increasing roasting time of shea kernels. This indicates that a free radical from the unsaturated fatty acid with the presence of an initiator such as heat (during parboiling) lipid oxidation can be initiated. Pokorny *et al*. (2001) stated that, in the presence of free radical, propagation stage begins with addition of oxygen atoms to the free radical to form a peroxide (a peroxyl radical:ROO). Then the hydrogen removed from another unsaturated fatty acid and attaches to the peroxide to form a hydrogenperoxide (ROOH). Factors such as temperature, light, moisture, metals and oxygen affect rate of oxidation. Parboiling of fresh shea nuts could facilitate lipids oxidation and hence higher peroxide value in the butter produced from such kernel compared to butter produced from non-parboiled kernels (Table 4.6).

In West Africa, parboiling of the nuts are usually done to kill the embryo and thus prevent germination of the seeds. This method has the additional advantage of inactivating the lipases that are responsible for hydrolytic degradation of shea butter (Nahm, 2011). However, parboiling has positive influence in the

peroxide value level in shea butter and high level of peroxide value affects the quality of shea butter. Lower levels are an indicative of higher quality and vice versa.

It is therefore suggest that parboiling will decrease the quality of shea butter.

It is important to note that the West African Trade Hub (WATH) in collaboration with the United Nations Common Fund for Commodities (CFC), the Economic and Monetary Union of West African States (UEOMA), the Ghana Board of Grades and Standards (GBGS) and the African Organization for Standardization (ARSO) have proposed various export guidelines and regional Standards for the shea subsector (Perakis, 2009). What this means is that without addressing the issue of quality assurance by improving on shea farmers methods of processing the nuts, Ghanaian shea nuts products would be graded as inferior to other countries shea nuts products if parboiling method of fresh nut processing continue to be a Ghanaian practice. Omujal (2009) noted that Uganda shea farmers never practice parboiling of fresh nuts before drying and yet its shea products have never been reported to have higher free fatty acids levels as compared to other countries products. According to Perakis (2009), the Prokarite project in Mali intends to help establish regional and international standards of shea product quality with reference both to shea kernel and shea butter as a basis for enhancing „traceability" along the supply chain.

Free fatty acids profile and peroxide value are key parameters one could use to assess the quality of shea butter as they determine the potential for degradation and thus define the grades of shea kernel and butter (Lovett, 2004). The present work proved that parboiling of fresh shea nuts increased the levels of peroxide value but lowed free fatty acids percentages. The levels of free fatty acids and peroxide value in shea butter provide information on the degradation and potential

rancidity of the butter. The peroxide value is a measure of rancidity in its early stage and shows good correlation with organoleptic flavor (Omujal, 2009).

According to Obibuzor *et al.,* (2013), predominant fatty acids in shea butter are palmitic (3.55%), stearic (44.44%), oleic (42.41%), linoleic (5.88%), linolenic (1.66%). The determination of free fatty acids in this work revealed the following percentages for parboiled and non-parboiled kernel respectively: palmitic (2.38 and 16.1), stearic (1.71 and 11.6), Oleic (1.13 and 6.49), linoleic (2.60 and 17.61) and linolenic (2.59 and 17.5). The values obtained in this study for stearic and oleic seems to fall below the lower limits as compare to values reported by Obibuzor *et al*., (2013) values for stearic and oleic ranges between (39.74-44.64) and (40.7144.48) respectively. Values obtained by Obibuzor *et al*., (2013) for palmitic (3.36-4.44), linoleic (5.73-6.41), linolenic (1.66) were higher than parboiled shea kernels butter values but lower than non-parboiled shea kernel values. In comparison with values, for oleic (19.10-19.99) reported by
Aculey et al., (2012), both parboiled and non-parboiled shea kernels oleic values were lower. These differences in values could be attributed to geographical variation and processing methods from fruits collection to kernel and butter (Nahm, 2011). There have been reports that these factors could influence fatty acid composition levels of shea butter (Fintrac, 1999, Hall *et al*., 1996, Obobuzor *et al*., 2013).

The present work also revealed that there was clear distinctiveness between parboiled and nonparboiled shea kernel butter in the physical parameters. It is known fact that an ordinary

Ghanaian could accurately use sensorial characteristics to judge the quality of the shea butter. In this study, butter colour, taste and aroma were evaluated and the results obtained shows that parboiling of fresh shea nuts affects the sensory characteristics of shea butter produced.

Descriptive analysis performed on the responses given by individuals" showed that the color of butter derived from parboiled kernel appears to be „beige" in colour while the non-parboiled kernel butter looks „ivory-like" in colour (Appendix C, plate 4). Omajul, (2009) and Nahm (2011) observed butter colour to be yellow orange and whitish yellow, respectively. The „beige" colour observed in this study for butter from parboiled kernels butter could be synonymous with yellow orange while „ivory" colour for non-parboiled with the whitish yellow colours reported by Omajul (2009) and Nahm (2011), respectively. Because, according to Schaeffer (2008), „biege" colour has a shade of white that is, 10% saturated and 96% bright and „ivory" colour has a shade of white that is 6% saturated and 100% bright. With this description, the „beige" colour could share similarity with the yellow orange and the „ivory" with whitish yellow. Colour can be a good indicator of vegetable oil quality because change in colour of a vegetable oil is mainly attributed to peroxidation, pigmentation or contamination (Lewis, 1999). Omajul, (2009) attributed yellow orange colour of the butter to either peroxidation or pigmentation. By this inference, the colour of butter (biege) from parboiled kernel source could be attributed to peroxidation. The ivory colour for the non-parboiled on the other hand could imply less peroxidation. The choice of butter with respect to colour by local consumers varies from one person to another. Assessment made by Omajul (2009) revealed that 50% of his respondents prefer brown, 21% and 14% chose red and yellow colours respectively.

Aroma or smell of the butter was distinctively different from each other. The parboiled kernel butter tends to have intense nutty smell than the non-parboiled kernel butter. The score was

100% nutty smell for parboiled kernel butter and 80% was scored for mild and 20% no nutty smell for the non-parboiled kernel butter. The variation in smell of butter between the parboiled and non-parboiled kernel butter could be explained by the differences in the peroxide levels in each of them. Hydroperoxides formed during lipid oxidation further decomposes into alkoxyl radicals (RO·) which have high energy causes β-scission, the cleavage of aliphatic chain of fatty acids into low molecular weight compounds such as volatile hydrocarbons, alcohols, and aldehydes and non-volatile alcohols and ketones that are responsible for perceived nutty smell (Damodaran *et al*., 2008). Volatile aldehydes (Hexanal, heptanal, octanal, nonanal, decanal, *trans*-2-heptanal, *trans*-2-nonenal, *cis*-2-decenal, *trans*, *trans*-2,4-nonadienal, *trans-cis*-2,4decadenal) are the most important contributor to off-aroma that can be found in oxidized lipids including shea butter (Bail *et al*., 2009; Pokorny *et al*., 2001). A high peroxide value appears to be responsible for the development of rancidity and since this affects the nutritional, physical appearance, flavor and safety of oil, it is therefore indicative of low quality butter. The parboiled kernel butter was significantly ($p<0.01$) higher in peroxide and 100% nutty smell as compared to non-parboiled kernel source of butter. Furthermore, descriptive respondents for taste scored parboiled kernel butter to have 100% no bitter taste while the non-parboiled scored 100% mild bitter taste (Table 4.10). The mild bitter taste could be because of higher free fatty acids levels in the non-parboiled kernel butter compared to the parboiled.

The implication of this finding is that parboiling of fresh shea nut as unit operation in the production line must be avoided in order to produce high quality shea butter for international market. Shea kernel quality is a key consideration since higher fat content and quality implies higher return on the same amount of energy used to process unit mass of the kernel to butter.

**5.2 Effect of different storage containers of kernel on proximate composition of shea kernel and physico-chemical characteristic of butter extracted.**

Ferris *et al*. (2001) reported that while the volume of shea kernels that goes to the processors is consumed, that going through the itinerant traders during the peak season mostly ends up being stored by the assemblers and wholesalers to profit from scarcity during the lean periods. In Ghana jute bags from cocoa industry are widely used for kernel storage. According to report by Omujal (2009), containers such as polythene sacks, clay pots, low-density polythene bags, woven baskets, drum (plastic/ metallic), high dense polyethylene bags and gourd are used in Uganda and the polythene was rated as the most common storage material used. Considering the physical and chemical properties of shea kernel each of these materials would have different impact on the quality of the kernel and the butter produced. Karin (2004) observed that the recalcitrant properties of shea nuts, makes it storage very difficult. According to Omajul (2009) the variability in proximate and physico-chemical characteristics as a result of post-harvest handling practices including fruit harvesting, seed drying and storage have not been investigated. In this study, shea kernel fat/ butter samples extracted from each of the five different storage containers (jute sack, cardboard, synthetic fibre, plastic bucket and polythene bag) were analyzed and ANOVA test performed on quality parameters to evaluate storage containers effect.

### 5.2.1 Effect of different storage containers of kernel on proximate composition at seven (7) months storage.

The results of the analysis in Table 4.3 demonstrate the effect of the different shea kernel storage containers on the proximate composition after seven (7) months of kernel storage. The results revealed that no significance differences ($p>0.01$) was observed between the fat, nitrogen free extracts, carbohydrate, crude protein, crude fibre, ash and energy content among the storage containers used. The different storage container showed similar effect on kernel proximate composition except moisture content (MC). This result

could be anticipated because the temperature readings and relative humidity records within the different storage containers showed that there were no significant internal variation except relative humidity which was significantly ($p<0.05$) higher in Polyethylene bag and jute sack than the cardboard and therefore the contents of the containers in logical sense could not have been affected significantly different. Aculey *et al*. (2012) observed that high temperature and relative humidity greater than 65% poses kernels to a wide range of mould infection. Temperature and residual water in kernels induces both hydrolysis reaction of glycerides and the oxidation of unsaturated fatty acids (Megnanou and Niame, 2013). Smith, (1998), Manuwa and Muhammad (2011) reported that any increase in moisture content during storage will result in rapid spoilage of produce and hence moisture content is useful information of biomaterials. Moisture content of shea kernels was observed to be highest in polyethylene bag. Shea kernel kept in polyethylene bag had gained moisture content from 7.0% to 9.16% (30.86% increased) while those kept in cardboard reduced in moisture content from 7.0% to 6.77% (3.29% reduction) (Table 4.3). A good storage material should allow air circulation pass through the produce during storage to reduce moisture content of the kernel because, Maritnez *et al*. (2008) revealed that water generally favours hydrolysis of triglycerides in oil. The relative humidity percent recorded in polyethylene bag and jute sack were higher (26.22$^{o}$C and 77.68%) and the lowest was recorded in cardboard (25.92$^{o}$C and 74.58%). This could be basis for selecting cardboard as storage container for shea kernel.

The analysis performed on the interactive effect of processing methods of shea nuts and kernel storage containers indicated that the choice of containers will be determine by the processing method and the specific proximate constituent of the kernel one desired. It was observed that parboiled kernel stored in jute sack, synthetic fibre and polythene bag resulted to faster reduction of fat content as compared to non-parboiled kernels stored in the same storage containers. The non-parboiled kernels significantly ($p<0.05$) increased in nitrogen free extracts content when stored in

cardboard than in any other storage container (Table 4.4). Its again implies that cardboard could improve proximate composition of kernel when use for storage.

Mould infection on kernels was not significantly different among the storage materials perhaps the post-harvest handling practice used to derive kernels for this work prevented contamination and hence the low presence of mould in kernels as was assumed by Aye, (1989).

### 5.2.2 Effect of different storage containers of kernel on physico-chemical characteristics of butter produced

Table 4.8 shows the effect of kernel storage containers on free fatty acids profile and peroxide value in the shea kernel. The analysis indicated that high oleic content (7.75) was observed in kernel kept in cardboard container whiles the polyethylene bag had (7.08) and the least (6.91) was recorded in shea kernel which was kept in plastic bucket. Similar trend is observed with the linoleic, essential free fatty acids. On the other hand, peroxide value was recorded highest in kernel kept in jute sack, followed by polyethylene bag. This suggests that cardboard generally is best for storage of shea kernels as compared to others. Investigation on the effect of different shea kernel storage container on quality characteristics of shea kernel and butter needs to be examined further to assess their effect on the safety of food kept in them because there could be the possibility of contamination with hydrocarbons substance especially those coming from polymers. The present study, gives sufficient evidence to justify the option to use cardboard as storage container for shea kernel for domestic purpose or export.

### 5.2.3 Effect of different storage periods of kernel on proximate, free fatty acids and peroxide value characteristics

Investigation into the changes in proximate composition of shea kernel samples between the zero and seven months of kernel storage periods revealed that shea kernels generally increased in carbohydrate, crude fibre and ash contents while fat, crude protein and energy contents reduced significantly ($p<0.01$) (Table 4.2)

Carbohydrate content increased by 29.19%, ash and crude fibre contents by 69.88% and 338.66%, respectively (Table 4.2). Nitrogen free extract and moisture contents did not change significantly. Kernel fat, crude protein and energy contents generally decreased significantly ($p<0.05$) after seven months kernel storage. Kernel decreased in fat content by 15.46%, crude protein content 16.24% and energy content 11.84%.

The oleic acid content in kernel increased significantly ($p<0.05$) from 3.8% to 7.02% while peroxide value decreased from 6.92% to 3.69% at seven months kernel storage. Observation in this study indicates the possibility of improving shea kernel quality when it is properly stored for not less than four months before processing into shea butter because according to Regional Technical Committee Comments on Draft Africa Regional Standard for unrefined shea butter, (2006), peroxide content provide information on the degradation and potential rancidity of shea butter while oleic fatty acid content ranges between 50-57% in shea shea is preferable.

# CHAPTER SIX

## 6.0 CONCLUSION AND RECOMMENDATION

### 6.1 CONCLUSION

It can be concluded from the present study that:

1. Parboiling of shea nuts could influence higher levels of carbohydrate and crude protein contents and peroxide value of shea kernels but reduces ash and free fatty acid profile contents as compare to non-parboiling.
2. Shea kernel could best stored in cardboard containers.
3. Parboiling and non-parboiling of shea nut before drying did not significantly influence fungi load on shea kernel.

4. Shea kernel carbohydrate, nitrogen free extracts, ash, crude fibre contents could be improve when the kernels are kept for a period not less than a month than when they are used immediately after harvest.
5. Temperature and relative humidity are key factors determining variations in proximate, free fatty acids and peroxide value levels during shea kernel storage.

## 6.2 RECOMMENDATION

The following recommendations have been made:

1. Parboiling of fresh shea nut before drying could be appropriate for producing kernels for food industries because of higher carbohydrate, crude protein contents and lesser bitter taste of butter.
2. Non-parboiling method is appropriate for production of kernels for cosmetic, confectionery or food industries because it produces kernels of less nutty smell, high Oleic acid, ash and kernels could be kept longer without deteriorating due to oxidative process than the parboiled kernel.
3. In order to maximize carbohydrate, crude fibre, ash and nitrogen free extracts contents, shea kernels should be kept for not less than four months before usage.
4. Cardboard is the best container for keeping shea kernels and therefore stakeholder should be encourage for its usage in the shea industry.
5. Further research should be conducted on the effect of different shea nut processing methods on the unsaponifiable value and mineral contents.

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**APPENDICES**

## A. LIST OF TABLES

Table 1.Monthly mean temperature and relative humidity at the experimental site, CRIG Substation, Bole from July 2013 to February 2014

| Month | Temperature | | Relative humidity | |
|---|---|---|---|---|
| | Min | Max | 9.00am | 15.00pm |
| Jul-13 | 29.1 | 21.6 | 86.8 | 69.3 |
| Aug-13 | 29.1 | 20.9 | 86.9 | 73.7 |
| Sep-13 | 29.9 | 20.4 | 85.9 | 73.3 |
| Oct-13 | 33.9 | 21.5 | 79.2 | 63.4 |
| Nov-13 | 34.1 | 21.7 | 76.0 | 55.7 |
| Dec-13 | 35.0 | 21.0 | 52.3 | 30 |
| Jan-14 | 30.4 | 17.8 | 32.4 | 24.4 |
| Feb-14 | 36.4 | 22.6 | 64.7 | 36.4 |
| Mean | 32.24 | 20.94 | 70.53 | 53.28 |

**Source:** CRIG, Bole meteorological station

## B. FRESH SHEA NUTS TREATMENT ON QUALITY OF KERNEL AND BUTTER

a

b

c

PLATE 1. (a- fresh shea nuts heaped before parboiling, b-parboiling of fresh shea nuts in an iron cooking pot, c- sun drying of parboiled shea nuts on the floor in Northern Gha)

a b

PLATE 2: (a- Locally constructed Sheanuts drying oven, cercle de Dioila, Mali. Source: Perakis,( 2009) and b- Locally constructed solar driers for shea nuts at CRIG, Bole Northern Ghana)

## C. COLOUR OF NUTS AND BUTTER AFFECTED BY FRESH SHEA NUTS TREATMENT

a

b

c

d

PLATE 3: physical appearance of parboiled and Non-parboiled shea kernels (a& c non-parboiled shea kernels; b&d parboiled shea kernels before and after 214 days storage respectively)


a b

PLATE. 4: physical appearance of parboiled and non-parboiled shea kernel butter (a- parboiled kernel butter, b- non-parboiled kernel butter)

**D. Different types of shea kernel storage materials use in Northern Ghana**

a b

c d

PLATE 5: Shea kernel storage material use in Northern Ghana ( a- Metal drum; b-used cement bag; c-jute sacks mixed with synthetic fibre sack; d- synthetic fibre sack)

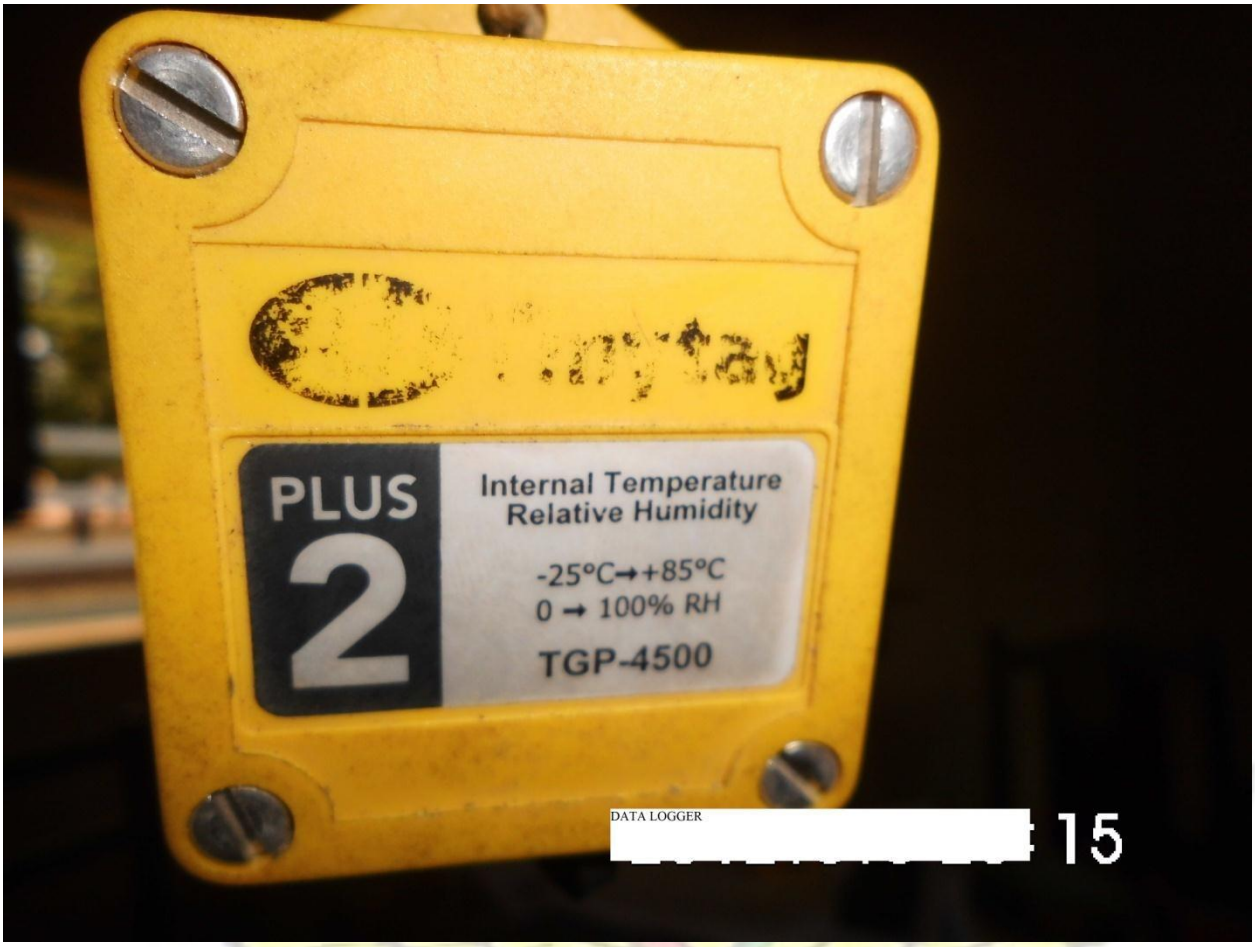


PLATE 6. TGP- 4500 Data logger

# HTML Color Chart with 140 Color Names

Please click on a color name to see the color as the page background and get matching colors along with HTML hex codes.

| | | | | |
|---|---|---|---|---|
| AliceBlue | DarkOliveGreen | Indigo | MediumPurple | Purple |
| AntiqueWhite | DarkOrange | Ivory | MediumSeaGreen | Red |
| Aqua | DarkOrchid | Khaki | MediumSlateBlue | RosyBrown |
| AquaMarine | DarkRed | Lavender | MediumSpringGreen | RoyalBlue |
| Azure | DarkSalmon | LavenderBlush | MediumTurquoise | SaddleBrown |
| Beige | DarkSeaGreen | LawnGreen | MediumVioletRed | Salmon |
| Bisque | DarkSlateBlue | LemonChiffon | MidnightBlue | SandyBrown |
| Black | DarkSlateGray | LightBlue | MintCream | SeaGreen |
| BlanchedAlmond | DarkTurquoise | LightCoral | MistyRose | SeaShell |
| Blue | DarkViolet | LightCyan | Moccasin | Sienna |
| BlueViolet | DeepPink | LightGoldenrodYellow | NavajoWhite | Silver |
| Brown | DeepSkyBlue | LightGray | Navy | SkyBlue |
| BurlyWood | DimGray | LightGreen | OldLace | SlateBlue |
| CadetBlue | DodgerBlue | LightPink | Olive | SlateGray |
| Chartreuse | FireBrick | LightSalmon | OliveDrab | Snow |
| Chocolate | FloralWhite | LightSeaGreen | Orange | SpringGreen |
| Coral | ForestGreen | LightSkyBlue | OrangeRed | SteelBlue |
| CornFlowerBlue | Fuchsia | LightSlateGray | Orchid | Tan |
| Cornsilk | Gainsboro | LightSteelBlue | PaleGoldenRod | Teal |
| Crimson | GhostWhite | LightYellow | PaleGreen | Thistle |
| Cyan | Gold | Lime | PaleTurquoise | Tomato |
| DarkBlue | GoldenRod | LimeGreen | PaleVioletRed | Turquoise |
| DarkCyan | Gray | Linen | PapayaWhip | Violet |
| DarkGoldenRod | Green | Magenta | PeachPuff | Wheat |
| DarkGray | GreenYellow | Maroon | Peru | White |
| DarkGreen | HoneyDew | MediumAquaMarine | Pink | WhiteSmoke |
| DarkKhaki | HotPink | MediumBlue | Plum | Yellow |
| DarkMagenta | IndianRed | MediumOrchid | PowderBlue | YellowGreen |

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PLATE.7 Colour Chart.