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SOIL PHYSICAL AND CHEMICAL PROPERTIES AND THEIR RELATIONSHIP WITH SHEABUTTER QUALITY IN SELECTED AREAS OF THE NORTHERN REGION OF GHANA

BY

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By

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DECLARATION

I, Adam Abdulai, hereby declare that this submission is my own research work towards the award of the Master of Philosophy Degree in Organic Chemistry and that it contains no materials previously published by another person or material which has been accepted or concurrently being used for the award of any other degree in this university or elsewhere, except where acknowledgment has been duly cited in the text and in the references.

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ABSTRACT

Soil physical and chemical properties and their relationship with the quality of shea butter, an extract of the kernels of the shea tree, were investigated in four districts of the Northern region of Ghana. Thirty-six samples of freshly extracted shea butter together with 36 soil samples were collected and stored at 25°C for analysis. The soil properties and that of properties of shea butter were determined using standard methods. The qualities of the shea butter were also examined based on their moisture content (MC), the peroxide value (PV), the insoluble impurities (IM) and free fatty (FAA) acids using a grading system set by the Regional Technical Committee of Africa standard for unrefined shea butter. A coefficient of determination (R^2) was used to establish the correlation between the soil properties and the quality and quantity of shea butter. The results indicated that soils at the shea parklands had sand forming the highest component (66.60 – 52.04), followed by silt (38.65 – 26.69) and lastly clay (9.31 – 4.73). The soil chemical properties such as organic carbon (OC), organic matter (OM) cation exchange capacity (CEC) and Nitrogen (N) were found to have poor correlation with the butter quality parameters. It was, however, found that the soil chemical properties of soil organic matter, soil organic carbon and cation exchange capacity correlates strongly with the fat content with R2 values ranging between 0.82 and 0.84. In conclusion, soil physical and chemical properties do not have a direct relationship with the quality of shea butter.

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DEDICATION

I would like to dedicate this work to my parents who gave me the opportunity to receive formal education. I would also like to dedicate this work to my lovely wife, Mrs. Adam Amina, for keeping the family together during this research when I was almost always missing in the family. And finally to our children: Adam Huzaima, Adam Fouzia and Adam Zakia, besides Sulemana Suraya.

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LIST OF ABBREVIATIONS

%	Percentage
^{0}C	Degree Celcius
ADW	Air dried (soil sample) weight
AOAC	Association of Analytical Chemists
AOCS	American Oil Chemists' Society
ATP	Adenosine Triphosphate
AV	Acid Value
BSc	Bachelor of Science
c	concentration
CBE	Cocoa Butter Equivalent
CEC	Cation Exchange Capacity
CFC	Common Fund for Commodities
DNA	Deoxy Ribonucleic Acid
EV	Esther Value
FAO	Food and Agricultural Organization
FFA	Free Fatty Acids
IV	Iodine Value
Km	kilimeter
KOH	Potassium Hydroxide
LSD	Least Significant Difference
MoFA	Ministry of Food and Agriculture
MPhil	Master of Philosophy
NADP	Nicotinamide Adenine Diphosphate
NN	Nanumba North

MOLGRD	Ministry of Local Government and Rural Development
OC	Organic Carbon
OM	Organic Matter
OOO	Oleic – Oleic - Oleic
pH	The negative logarithm of the hydrogen ion concentration
PV	Peroxide Value
p	probability
Rpm	Rounds per minute
RTC	Regional Technical Committee
SG	Specific Gravity
S-N	Savelugu-Nanton
SOO	Stearic – Oleic – Oleic
SOS	Stearic – Oleic - Stearic
SP	Specific Gravity
USAID	United States Agency for International Development
USV	Unsaponifiable Value
WARS	West African Regional Standards

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

In the last decade, conscious efforts have been made by many researches (Motlhanka *et al, 2008;* Moore, 2008) to unravel the potential impact indigenous trees have on the sustainability and improvement of livelihood. The trees are basically not cultivated. However, they play a vital role in supporting the livelihoods of people living in rural areas (Motlhanka *et al, 2008*). Analysis of the nutritional contents of these indigenous fruit bearing tree species have shown that many are rich in sugars, essential vitamins and minerals (Maghembe *et al*, 1994). The fruits and the seeds of these trees are potentially serving as the main source of edible vegetable oil and protein for many rural people (Moore, 2008). One of such indigenous trees, which is of great value to the inhabitants of rural communities in Northern Ghana, and Africa as a whole is the shea tree.

The Shea tree (*Vitellaria paradoxa*, C.F.Gaertn*)* grows naturally in the wild. They are common in the agro-forestry parklands in the dry Savannah belt of West Africa. They stretch their occupancy from Senegal in the west to Sudan in the east, and onto the foothills of the Ethiopian highland, where they are protected and managed (Maranz et al., 2004). Other researchers (FAO, 1988a in Fobil, 2002; DFSC, 2000 in Carette et al., 2009; Manasieva, 2011), have it that, the Shea trees occur exclusively in 20 countries across the African continent. These countries include Benin, Ghana, Chad, Burkina Faso, Cameroon, Central African Republic, Ethiopia, Guinea Bissau, Cote D'Ivoire, Mali, Niger, Nigeria, Senegal, Sierra Leone, Sudan, Togo, Uganda, Zaire, Guinea, Democratic Republic of Congo and Kenya (**Figure 1.1**)

Figure 1.1: Shea growing areas in Africa

In Ghana, most of the Shea parklands occur extensively in the Guinea savannah ecological zone, which is characterized by total annual rainfall of about 1,000–1,300 mm/annum (MoFA, 2011). They also occur less abundantly in the Sudan Savannah which normally records precipitation below 1,000 mm/annum (MoFA, 2011).The shea parklands are distributed to cover almost the entire area of Northern Ghana. They occupy over 77,670 square kilometers in Western Dagomba, Southern Mamprusi, Western Gonja, Lawra, Tumu, Wa and Nanumba with Eastern Gonja having the densest stands. Nonetheless, there is sparse shea tree cover found in Brong-Ahafo, Ashanti, the Eastern and Volta regions in the south of the country (FAO, 1988, in Fobil, 2002, Hatskevich *et al, 2011*).

Figure 1.2: The Native Shea Parkland

Source: Researcher's Field Work

Shea trees are plant species that grow naturally in the wild (Figure 1.2). It derives its water and nutrients from the soil for healthy growth and for manufacturing of its food. The soil also provides the plant with anchorage and stability (FAO, 1999). However, a soil potential for supporting plant growth is largely determined by the environment that the soil provides for the growth system of the plant. The capacity of soil to support plant growth and yield depends on its nutrients level. Soil fertility status is generally correlated with crop yield, low on infertile soils and high on fertile soil (Parnes, 1990). The nutrient variations of a soil constitute the most important factor which influences crop yield and the variability of the quality of its product (Bado *et al., 2006*). The various elements that measure soil fertility are not evenly distributed among soil types but rather reflect what exist in the parent materials that were weathered to form the soil (Jones and Benton, 2003).

The nature of soils in any particular area depends on the geological processes that led to formation of rocks and the subsequent weathering of such rocks (Abubakari *et al.,*

2012). This in effect results in the formation of various soil types. Shea tree distribution in the savannah parkland is influenced by climatic and soil factors. The vital soil factors identified to affect the Shea tree distribution are the soil physical and chemical properties either acting independently or in combination (Abubakari *et al., 2012*).

The soils in northern Ghana are described generally as savannah ochrosols and groundwater laterites. They are formed over granite and Voltaian shales. They however appeared to have varied in the Shea parklands as a consequence of the different geological materials and processes that served as the root for their formation (Abubakari *et al., 2012*). Over the years, the physical, biological and chemical compositions of the soil within the three Northern Regions have experienced drastic changes. This is due to diverse and changing land uses that characterized the savannah landscape (Abubakari *et. al 2012).* According to Fontaine *et al., (2004),* the soil in the Northern Region generally varied from loamy sand, sandy loam to loam. This in effect resulted in the variability of soil nutrients leading to the differences of cation exchange capacity across the Shea parklands.

The Shea tree is highly valued by farmers, mostly due to its fat containing nuts which are sold both in local and international markets. It contributes considerably to wealth creation. Furthermore, the commercialization of Shea products represents an important source of income at different levels of the society. This has taken its root from the rural children and women who gather and process the nuts, to town dwellers as well as entire countries (Boffa, 2000). The vegetable fat of shea nut is second in importance only to palm oil in Africa (Hall et al., 1996). The importance of the shea tree in Ghana's economy became even more significant with the need to find

substitutes for cocoa in the confectionery and cocoa butter industry in the early 1970s (Moore, 2008).

The collection and processing of shea nuts is central to women's household responsibilities (Carney *et al., 2009*). Rural women engage in the gathering and processing shea butter in West Africa since at least the mid-fourteenth century. Shea nuts are processed into shea butter using different processing methods. However, in Northern Ghana, the predominant shea butter extraction processes is the traditional method, but chemical and mechanical extraction methods are employed in the shea butter processing plant at Buipe and Savelegu.

The shea nut, which contains over 50% fat, remains an essential source of nutrition for rural dwellers in Northern Ghana. The butter extracted from nuts is the main edible oil for the people. It is serves as the most important source of fatty acids and glycerol in their diet. It is an unguent for the skin (Carney *et al., 2009*). It also has anti-microbial properties, which gives it a place in herbal medicine as a sedative or anodyne for the treatment of sprains, dislocations and the relief of minor aches and pains (Carney *et al., 2009*).

Also, the pharmaceutical, cosmetic and soap industries use the butter as an important raw material or a precursor for the manufacture of soaps, candles, and cosmetics (Adomako, 1985). Furthermore, its by-products, the brown solid that is left after extracting the oil and the hard shell of the nuts are used as a water-proofing material on the walls of mud-buildings to protect them from the eroding forces of the wind and rain (Marchand, 1988).

As Shea butter is becoming recognized as a commodity significant to the development of the economy of many African countries including Ghana, the

physico-chemical composition and fatty acid profiles of Shea oil have been reported for both West Africa and Uganda (Maranz *et al., 2004*). Moreso, the differences that exist between these properties have been established in some countries. These variations have been attributed to environmental factors such as rainfall, maturation period, agronomic practices and genetic substitution (Sonau *et al., 2006*). It has been remarked that, soil fertility may also have some influence in the proprieties of the shea butter (Okullo, 2010).

Although the physical and chemical properties of shea oil, have been reported in some of the African countries, increasing demand worldwide for exportable products calls for more work that will contribute to its certification. The characterization of physico-chemical properties of Shea oil originated from the soil of Ghana which is part of West Africa, is one step towards developing its certification system. Therefore, an analysis of the physical and chemical properties of the soil in different Shea parklands, that is expected to provide the necessary information about the distribution and dynamics of physicochemical properties of the butter extracted from Shea nuts obtained in difference soils in selected areas in Northern Region of Ghana, is the interest of this research.

1.2 Statement of the Problem

The shea tree in recent times has become an important economic indigenous plant in most African countries including Ghana. This is due to the heavy demand of its butter, both locally and internationally (Carney *et al., 2009*). The kernel of the shea fruits are high in oils and have long been collected and processed by women in savannah communities into butter (Kent and Bakaweri, 2010). The inhabitants of Northern Region of Ghana depend on the Shea butter as the valuable natural source

of vegetable oil. The butter serves as a source of income for the support of their livelihood. It is also used for cooking, manufacturing of local soap and for treatment of body pains and many ailments. In addition, this exceptionally rich vegetable extract have been reported to contains fatty acid triglycerides, and a high amount of unsaponifiable matter which stimulate the skin's natural renewal process (Asuquo et al, 2010). Equally, unrefined shea butter oil is superior to the refined one, in the sense that it retains all its natural vitamins, especially vitamins A and E. Also, the fat extracted has cosmetic and pharmaceutical uses (Asuquo *et al, 2010).*

The butter, which is a member of the family of lipids is chemically composed of fatty acids such as palmitic acid (**C16**) , stearic acid (**C18**), oleic acid (**C18**) and linoleic acid (**C18**) (Tooley, 1971). The composition and the quality of the butter are being influenced by several factors notable among them are the geographical occurrence of the shea tree, its botanical origin, post harvest handling of the seeds and the processing (Asintoke, 1987). Since shea butter is an extract of shea nuts obtained from the shea tree which derived its nutrients from the soil, it is important to investigate soil physical and chemical properties and their relationship with shea butter quality.

There is a report by Abubakari *et al*. (2012) on the effect of geographical gradient and land use history on soil physical and chemical properties in the Shea parkland. According to them location of shea parklands had some significant effect on the physical and chemical properties of soil irrespective of the land use class and the land use history. This they said influenced soil nutrient factors such as particle size distribution, pH, organic matter, nitrogen and phosphorus, exchangeable bases,

exchange acidity as well as effective cation exchange capacity. These properties however, have not been correlated to Shea butter quality.

Parameters like viscosity, colour and refractive index, which constitute the physical properties and the chemical parameters such as iodine number, acid value, peroxide value and tocopherol level, fatty acids profile as well as saponification value and unsaponifiable matter, have been used to characterize the quality of the Shea butter in some countries in West Africa. This therefore underscores the need for information on soil physical and chemical characteristics and their relationship with shea butter physicochemical properties across selected shea parklands in four districts in the Northern Region of Ghana

1.3 Objectives

1.3.1 General Objective

The general objective of the study is to examine the relationship between soil physical and chemical properties and the quality of shea butter in selected areas of Northern Region of Ghana.

1.3.2 Specific Objectives

The specific objectives of the study include:

1. To determine the chemical and physical properties of soil from identified shea tree parklands in the selected districts in the Northern Region of Ghana.
2. To locally extract and determine the physico-chemical composition of shea butter from shea nuts collected from the identified shea tree parkland in the selected districts.

3. To examine the quality of the butter in the selected district according to West Africa Regional Standard on the quality of unrefined shea butter.

4. To establish the relation between soil physical and chemical properties and the quality of shea butter.

1.4 Justification

The Shea butter is a natural fat extracted from the nuts of Shea tree which are found in savannah parklands. The parklands are said to be distributed over almost the entire area of Northern Ghana. The distribution of the parklands has been attributed to climatic, vegetative and soil factors. These factors appear to have been varied from one area to another in the Shea parklands within Northern Region of Ghana. For centuries women in this area collect the nuts and processed them into butter.

Many exclusive lines of cosmetics use products made from the extracted butter, for natural skin moisturizers, lip balms, and eye creams (Carney *et al., 2009*). The butter is also prized for its superb healing and moisturizing properties. It is an important ingredient in sunscreens, conditioners, and in the treatment of burns and muscle pains.

Commercial interest in Shea butter also centres on its use as a substitute for cocoa butter in the chocolate industry. Also the use of Shea butter has widened its scope to embrace food, pharmaceutical and soap industries. These industries demand for specific quality of the Shea butter which depends on its physical and chemical properties such as the iodine number, acid value, peroxide value and tocopherol level, fatty acids profile, saponification value as well as unsaponifiable matter.

But the Shea tree is a plant species which depends on soil nutrients for healthy growth and production. However, soil in different geographical environment varies in terms of physical and chemical composition. This can result in the variation of nutrients levels of the soil which can affect the growth of plant and the quality of its products especially its fat content. Since soil fertility has an influence on plant growth and the quality of plant product, this work will find the extent to which soil physical and chemical properties may influence the physicochemical properties of shea butter.

The outcome of this research would not only provide information on the quality of shea butter but would also establish the relationship between soil properties and Shea butter quality in selected areas in the Northern Region of Ghana. Furthermore, the information obtained can also be used to improve marketing and utilization of shea butter and shea related products in the region. The research would also grade shea butter based on the quality requirement for various products and reference point for further research on quality and commercialization of shea butter in Ghana. Finally, this research work fills information gap about the specific nutrients and type of soil suitable for healthy growth of shea plant and for possible cultivation.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Soil, Climate and Vegetation in the Northern Region of Ghana

Soil is a natural medium for plant growth. It is the most valuable natural resource a nation possesses (Obeng, 2000). There are, however, different types of soils with different suitability rating for the healthy growth of plants. Fertile soil is essential for producing healthy plants with high yield and nutritious products. The physical and chemical characteristics of the soil are significant indicators of soil quality that can directly or indirectly influence the healthy growth of plants and the quality of its product (Peters, 2002).

The type of soil in any locality depends on several factors. These include, as mentioned, the parent rock, the climate, the relief, the drainage, the living organisms on the land and the time taken for a particular parent material to break down into soil (Obeng, 2000). Such is the importance of the climate among these factors that in Ghana, soil zoning are put into two based on the two major distinct vegetation zones; namely forest and savannah of which Northern region of Ghana falls within the savannah zone (Obeng, 2000).

The Northern region is covered by a tropical climate marked by the alternation of dry and rainy season. It experiences a mono-modal rainfall pattern, beginning in May and ending in October, with an average annual rainfall of 750 to 1050 mm. The dry season is between November and April. Temperatures are high almost throughout the year with the highest of 37 ^{0}C in March and April. However, lower temperatures are experienced between November and February, the harmattan period.

Geologically, the region is characterized with sedimentary rocks predominantly the voltaian sandstones, shales and mudstones. The soils derived from the above parent materials range from ground water laterite, savannah ochrosols, sandy soils, alluvial soils and clay. These types of soils vary in terms of physical and chemical composition and therefore influence the quality of plant product separately.

The vegetation of northern Ghana is described generally as Guinea savannah. It consists predominantly of grassland, especially savannah and characterized with drought tolerant plant species such as the shea tree, dawadawa, baobabs or acacias and ebony which form an integral part of the people's livelihood (Saeed, 2012).

2.2 Morphology of Shea Tree

The shea tree is made up of *Vitellaria paradoxa* and *Vitellaria nilotica* as the main varieties in Africa (Vermilye, 2004). However, the largest exported volume grows throughout the West African region including Ghana is the *Vitellaria paradoxa*. The *Vitellaria nilotica* predominate in northern Uganda and southern Sudan (Enaberue et al, 2014).

The *Vitellaria paradoxa* (Maranz et al., 2004) belongs to the saponaceous family (Hatskevich et al., 2011). It is a deciduous tree of medium size, with a pyramidal crown. A fully mature Shea tree usually grows to an average height of about 15 metres (Agyenty-Badu and Kwame, 2010), but on rare occasions they have been recorded to grow up to 25 metres (Maydell, 1990). The tree has a cylindrical trunk with a circumference between 0.52-5meters, usually relative to the height of the tree and measures on average 3-4 meters before splitting into numerous branches with thick, fissured bark (Moore, 2008).

The leaves are green and are arranged spirally, mostly in dense clusters at the tips of branches (Nikiema & Umali, 2007) as shown in **Figure 2.1(I)**. The flowers are greenish-yellow colour and appear in groups of approximately 30-40 during the flowering season which is between December and March (Maranz & Wiseman, 2003). The fruit is green in colour**, (Figure 2.1(II)** spherical berry and is harvested when fully matured (DeMoss, 2001). Within the fleshy spherical berry is the nut which in turn, houses the kernel (Fobil, 2010).

Figure 2.1: Morphology of Shea Tree

Source: Researcher's Field work

2.3 The Habitat and Optimum Growth Conditions of Shea Tree

The Shea trees are native to tropical African parklands and are the most dominant and abundant species found in semi-arid areas of at least 19 Sub Saharan African countries (Hall *et al*., 1996). The trees are relatively adaptable species, reflected in their large geographical distribution. They however have optimum conditions under which growth will be fastest and healthiest (Moore, 2008).

The Shea trees thrive well on dry sandy soils that have a good humus cover, but will be found on a variety of soil types (Hall et al., 1996). The species seemed to avoid land susceptible to flooding (Agyenty-Badu and Kwame, 2010). They have extensive, relatively shallow rooting systems which help them to tolerate extended dry seasons which can last up to 8 months as well as the occasional droughts experienced characterizing savannah zone (Vermilye, 2004). However, their shallow rooting systems do not provide much anchorage and makes them particularly vulnerable to being blown over in strong rainstorms which regularly occur in the wet season (Moore, 2008).

The shea trees which are indigenous to the savannah zone are quite light demanding trees. They thrive well in plentiful sunlight. However, the importance of sunlight decreases with age and a position in the shade will not affect the continued growth of a mature tree (Moore, 2008). They are very resistant to bush fires (Quansah and Schlup, 2012)

Although the shea trees are generally the dominant species on agro-forestry parklands, they are often associated with other species of tree plants (Boffa, 2000). The tree appears not to be distressed by any possible sources of competition. It even thrives well in a competitive environment (Moore, 2008). The Shea tree, like most other tree and bush species are highly vulnerable to being trodden by grazing livestock in their plantlet stage and so a more thickly vegetated environment increases the protection for tree, thereby increasing the likelihood of maturing into a larger, more robust tree (Hall et al.,1996).

2.4 Soil Nutrients Effect on Plant Growth

The plant growth in the context of crop production demands conditions adequate to yield a crop which is economically worthwhile. For efficient plant production, it is important to understand the soil environment in which the plants grow (Catriona *et al*, 1999). Soil is described as the storehouse of most of the plant nutrients essential for plant growth (Peter *et al*, 2000). It is considered as a complex natural material derived from weathering of rocks and decomposition of organic materials, which provide nutrients, moisture and anchorage for plants (Manjula, 2009). In fruit tree, like shea tree, perhaps more than in any other plant, nutrient imbalances may manifest themselves in quality characteristics of the fruit and its products or otherwise normal appearing trees (Manjula, 2009).

Different soil types have different nutrient levels which are blended together in differing amounts which determines the type of soil. Soil physical factors, especially soil structure, texture aeration and moisture as well as soil micro organisms have a major influence on plant growth and root development. Soil chemical factors like pH, nutrient availability and cation exchange capacity also greatly influence plant growth (Morgan and Connolly, 2013).

A well textured and structured soil would have the correct percentage of sand, silt and clay which is arranged together in the correct manner to allow aeration, drainage and microbial activity to occur. Nutrient availability varies from one environment to another. At some levels nutrients could be deficient and at other levels it is high (www.landscapeinfoguid.com.au). Shea tree parklands which occurred in the different environment would have unbalance nutrients availability. This infect would affect their yield and the quality of their product.

2.5 The Importance of the Shea Tree

The Shea tree is an indigenous economic tree. As mentioned earlier, it is important for the livelihoods of the rural population as it has been for centuries. Almost every part of the tree has some use. The fruits are highly nutritious and have multiple uses (Moore, 2008).The fresh fruits are eaten and are also processed into nuts which are sold in both local and international markets for income (Akrofi and Amoah, 2009).

Besides, several useful products are obtained from the nut. But the most valued product is the shea butter (Hall *et al.,* 1996).The butter contains about 60% edible fats (Axtell *et al*., 1993). The fat content also makes the butter an ideal candidate for use as a raw material for cooking oil, margarine, soap, detergents and candles (Akosah-Sarping, 2003).

The significance of the shea tree to the economy of Ghana grew to become even more important in the early1970s when it was made known that it is one of the only six plant species whose vegetable fat can be used in the manufacture of Cocoa Butter Equivalents (CBEs) in chocolate as well as being a valued ingredient in the pharmaceutical and cosmetics industries (Official Journal of the European Communities, 2000).

Apart from the fats, the residual product, after the butter is extracted does not only serves an excellent ingredient for livestock feed production (Axtell et al., 1993) but also used as fuel. It can also be mixed with mud for plastering traditional mud huts. The husks obtained from the nuts have the tendency to remove considerable amounts of heavy metal ions from wastewater (Fleury, 1981; Eromosele & Otitolaye, 1994). The leaves of the tree are used as fodder and also as an ingredient for making alkaline and paint (Lovett and Haq, 2000; Carette *et al*., 2009; Hatskevich *et al*., 2011).

2.6 Shea Butter Extraction Processes

2.6.1 Shea Fruit Harvesting

In harvesting, the matured ripe fruits of the shea tree are allowed to fall down under the influence of gravity by themselves beneath the mother tree (Karin, 2004). This ensures that only fruits that are fully developed and ripe are harvested. It was revealed that harvesting the fruits directly from the top of the tree with the use of sticks or shaking allowed the undeveloped fruits to be harvested. If this is not avoided the yield of the oil as well as its quality will be reduced. The harvesting is done by the fruits being picked from the ground around the shea parklands. They are picked by hands, gathered at one spot, collected and transported home for processing (**Figure 2.2**).

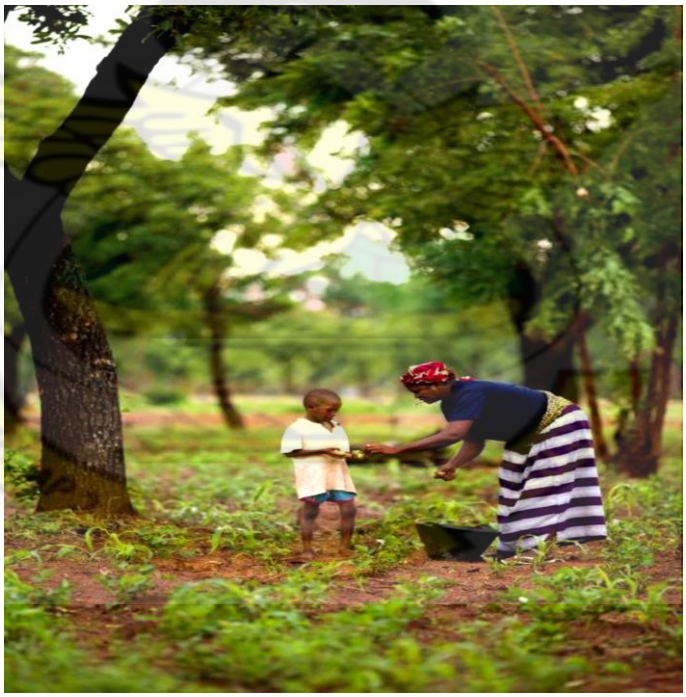


Figure 2.2: Shea nut picking

Source: Global Shea Alliance, (2013).

2.6.2 Shea Kernel Preparation

The preparation of the kernels is done by first removing the pulp of the fruit, a process known as depulping through fermentation. Afterward, the depulped nuts are boiled to clean the surface of any remaining fruit pulp. The boiling does not only clean the nuts but also softens the shell, ready for easy removal. Furthermore, boiling kills the embryo which prevents seeds germination, with additional advantage of inactivating the lipases that are responsible for hydrolytic degradation of shea butter (Hee, 2011).

The boiled nuts are then sun dried for about 5-10 days **(Figure 2.3.I).** The drying process facilitates de-husking, the process employed to remove the hard shell or coat covering endoderm containing the oil (Moore, 2008). The dried nuts **(Figure 2.3 I)** are de-shelled either using a pestle and mortar or by hand to obtain the shea kernel **(Figure 2.3 II).**

The kernels are further sun dried for several days to remove the moisture content, as much as possible. A research has shown that, the shea kernels can be kept for several years without spoilage if its moisture content is maintained between 6% and 7%. This drying process is significant since it inactivates enzymes facilitating the build-up of fatty acids in the kernel (USAID, 2004).

(I) Dried Nuts With shells (II). Dried shea Kernels

Figure 2.3: The Processing Stages of the Shea Nut
Source: Researcher's Field Work

2.6.3 Shea Kernel Storage

Shea kernels after preparation are stored in sacks, woven baskets, broken pots and plastic buckets that are kept either in house, or kitchen floors. In some cases they are hanged in houses or kitchens instead of floors. In recent time, jute bags from cocoa industry are widely used for the storage of the kennels. Over the past years, polythene bags or sacks were the common storage materials **(Figure 2.4).** However, this had been reported to stimulate fungal growths which adversely affect kennel quality because they do not allow air circulation (FAO and CFC, 2005).

Figure 2.4: Storage of shea kernels
Source: Researcher's Field Work

2.6.4 Shea Butter Extraction Methods

In recent time, the technologies that have been reported for the extraction of shea butter are the traditional boiling, mechanical, chemical and biological methods (USAID, 2004).

2.6.4.1 Traditional Extraction Processing Of Shea Butter

In this method, the dried shea kernels are broken down into smaller particles **(Figure 2.5A).** This is done by the use of wooden mortar or grinding stone or mill. The breakdown of the kernels increases their surface area as well as breaking the intra molecular forces that binds the nuts. The reduced particles of the kennel are then roasted **(Figure 2.5B).** This process partially burn the non-oil organic matter and converts water soluble compounds which exist in combination with the oil into a paste-like mixture of solid and liquid.

The roasted kernels are transported to the grinding mill where it is ground into paste **(Figure 2.5D),** to further increase the surface area. Water is used in this method to separate the oil from the non- oil solid particles, through a process similar to froth flotation (Apea and Larbi, 2013). In the process, water is added to the paste-like mixture, followed by mechanical agitation a process known as kneading **(Figure 2.5E)** until froth is formed.

It is reported that the froth is usually obtained slightly above room temperature (27.6^0C) (Apea and Larbi, 2013). The froth is then skimmed off the surface **(Figure 2.5F)** of the mixture, put into a cooking pot and boiled **(Figure 2.5G)** until the oil begins to float on the surface. When the oil eventually collects at the surface, with the heavy impurities settled at the bottom, the oil is scooped off into a separate container

(Figure 2.5H) and left overnight to rest for it to solidify. Afterward the extracted butter is transferred into storage plastic or glass containers.

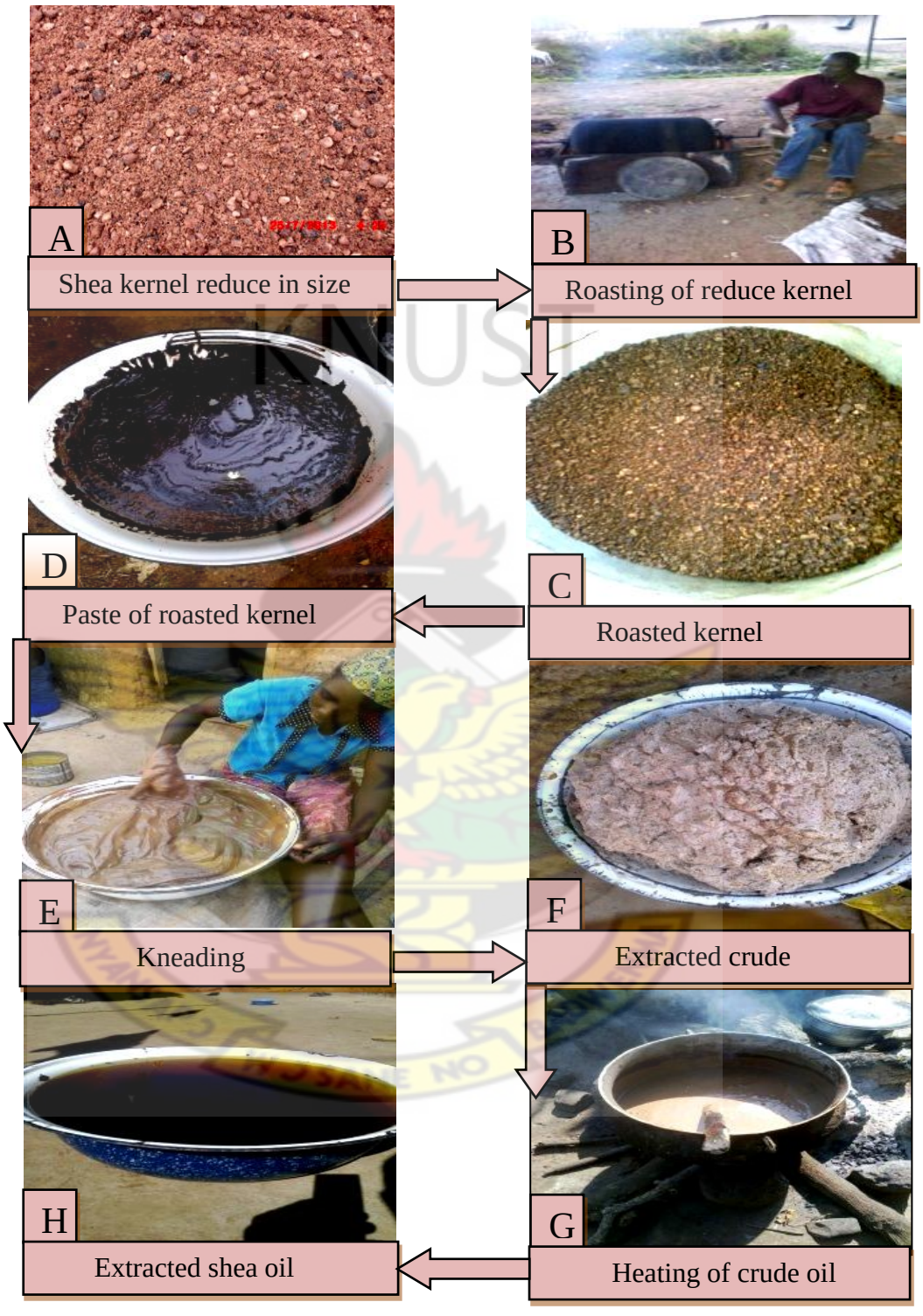


Figure 2.5: Flow Chart for Traditional Extraction Process of Shea Butter

Source: Researcher Field work

Although, the traditional method is found to be labour intensive, time consuming and wasteful, it has an advantage of producing pure and natural shea butter (Masters and Puga, 1994). It is also the largest common method of extraction familiar to rural woman in West African sub-region.

2.6.4.2 Mechanical Pressing Extraction Method

The mechanical pressing method of shea butter extraction has been reported by FAO and CFC (2005).This technique is carried in a plant comprising of boiler, mechanical press system and a filter press system. In extraction, the dry kernels are feed into the boiler where they are cooked and transported into the mechanical press. The oil is pressed out with some traces of the residues accompany the extracted oil. The residues are filtered out through the filter press to obtain clear oil which is allowed to cool and solidify.

It is a method recommended for the large production of commercial quantity of shea butter. The method was not only developed to increase productivity and save time, but to reduce stress on the processors since traditional boiling method was found to be labour intensive and time consuming (Masters and Puga, 1994).

Notwithstanding the advantage of the mechanical press method, it cannot be made assessable to small scale local industries which predominate in most developing countries including the Northern region of Ghana.

2.6.4.3 Solvent Extraction Method

In this method, the dried kernels are being crushed into paste which is then fed into the Soxhlet extractor. Afterward an organic solvent such as n-hexane or ether is

added. The mixture is allowed to stand for some number of hours for the oil to be separated which is decanted and allowed to solidify.

The types of the solvents used in the extraction have some influence on the quality characteristics of the butter especially the total vitamin E content and peroxide value of the butter. In a study conducted by Kar *et al* (1981) on the best solvent for shea butter extraction, petroleum ether, n-hexane, chloroform, benzene, and water were employed. The outcomes was that, water extraction yielded almost half or less amount of total fat from the kernel, contained higher values of peroxides with no detectable levels of vitamin E. It has also observed to promote the oxidation of the butter. The use of organic solvent extraction has been acknowledged to give a higher yield, contained nearly 0.01 % of vitamin E and showed no detectable level of peroxides.

Although the use of organic solvent for shea butter extraction give a high yield, it is considered not to be wholesome for consumption due to some traces of the solvent that may remain in the butter (Apea and Larbi, 2013). Also solvent system can sometimes be used for commercial extraction of the butter in developed countries; it is mainly developed for laboratory experiment.

According to FAO and CFC (2005), this method is not usually used in domestic and commercial shea butter extraction in developing countries due to its high costs involved, environmental problems and lack of technical skills associated with it.

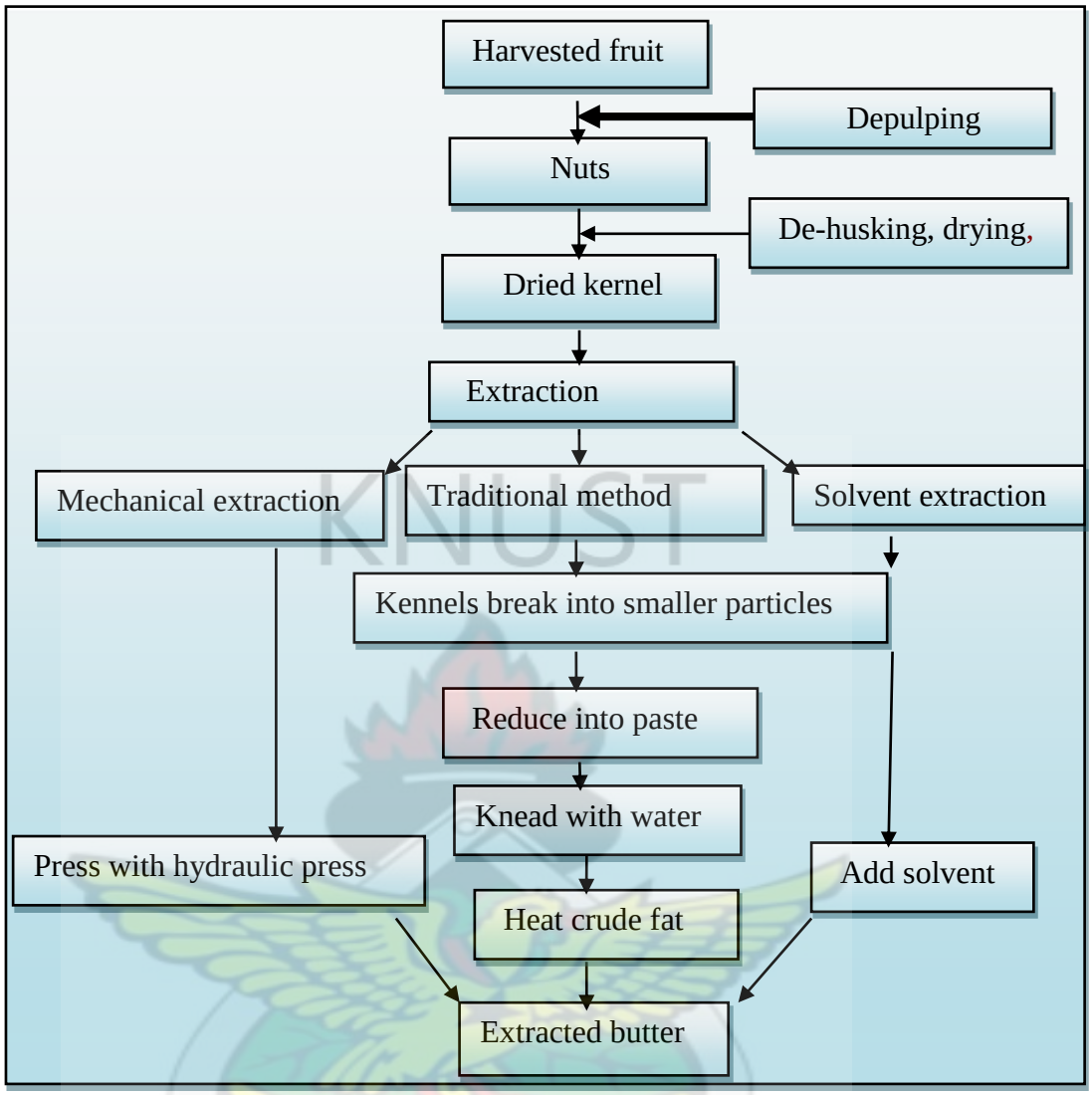


Figure 2.6: Flow Chart for the Processing of Shea Butter

Source: Researcher's Field Work

2.7 The Basic Chemistry of Shea Butter

Shea butter is a natural product. It occurs in shea plants as storage lipids; a class of organic compounds which distinguish itself from other compounds on the bases of their inability to dissolve in water but are soluble in non-polar solvent (Zurao *et al*, 2011). As a plant fat, it is said to be made up of glycerides or glycerol esters of long chain fatty acids (Agyenty-Badu and Kwame, 2010). Five principal fatty acids are

identified to be associated with the glycerides of butter. These fatty acids are either saturated or unsaturated. They include palmitic (16:0), stearic (18:0), oleic (18:1), linoleic (18:2) and arachidic (20:0) acids.

In terms of the composition of the fatty acids in the butter, stearic and oleic acids dominate almost 40-45 % of total fatty acids respectively. Linoleic acid generally ranges from 5-10 %; followed by palmitic acid at 4 % (Alander, 2004) with arachidic acid takes the lowest amount. Maranz *et al*. (2004) also reported shea oil fatty acid composition to be dominated by stearic acid and oleic acid, which together account for 85-90% of the fatty acids. Adikini (2002) in his research also established the dominant fatty acid in shea butter to be oleic and stearic acids with percentage composition of 57% and 30% respectively. It is reported that the fatty acid composition of the butter varies with its geographical source (Frank et al, 2007)

Table 2.1: Reports on Shea Butter Fatty Acid Composition

	Sources		
Parameter (%)	**(FAO,2007); Omujal, 2009)**	**(Prokarite, 2007; Omujal, 2009)**	**(Adomako, 1985 ; Agyente and Kwame , 2010)**
Stearic acid	30-41	31.2	45.5
Oleic acid	49-50	56.5	40.8
Palmitic acids	5-9	4.5	4.8
Lioleic acid	4-5	5.8	6.9
Arachidic acid	…….	1.0	……..

Besides the glycerides, the butter is also said to be made up of a minor unsaponifiable fraction which contains some bioactive substances such as hydrocarbons, tocopherols, sterols, and alcohols and thus responsible for shea butter's medicinal properties

(Esuoso *et al.,* 2000). However its tocopherol content is said to have been affected by the climate under which it grows (Maranz et al., 2004).

2.8 The Triacylgyceride Variation of Shea Butter

The triacylglyceride of fats consists of fatty acids attached to a glycerol backbone (Hee, 2011) as shown below.

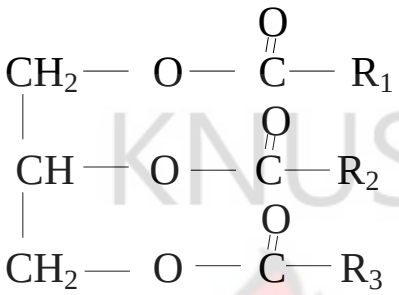
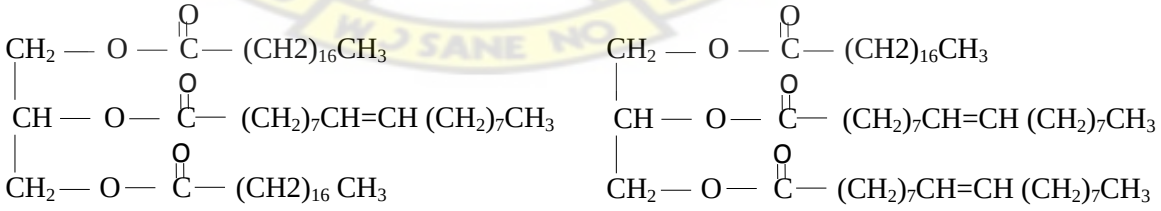


Figure 2.7: General Structure of Triacylglycerides

R_1, R_2 and R_3 represent individual alkyl groups.

The R groups are either saturated or unsaturated (Agyente and Kwame, 2010). As there is the occurrence of different fatty acids in shea butter, different combinations of fatty acids attached to the glycerol are possible and a possible occurrence of different triglyceride. In the butter, the most common combinations are SOS (S-Stearic, O-oleic) and SOO (Fig.2.8 (I) and (II)) which are said to be made up of 40% and 27 % respectively of the total triacylglycerol molecules (Alander, 2004).



(I) SOS triglyceride **(II) SOO triglyceride**

Figure 2.8: The common fatty acid combinations of triglycerides

Other possible combination is reported to include POS (6%) and POP (1%) (Alander, 2004). Also according to Di Vincenzo *et al (*2005), the major triglycerides in shea butter with regional variation include; SOO, OOO, and SOS.

2.9 Shea Butter Physico-Chemical Properties

2.9.1 Physical Parameters

The physical characteristics as acknowledged for quality characterization of fats or oil mention parameters like colour, refractive index, pH, viscosity and specific gravity. These parameters play a significant role in determining the quality of any oil since they furnish information on the physical specification for oil description (Lewis, 1999; Omujal, 2009).

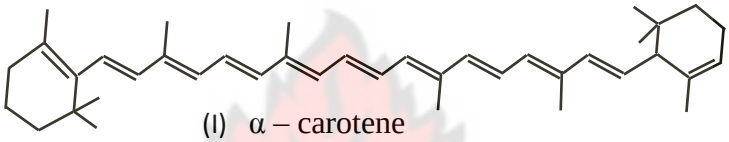
2.9.1.1 Refractive Index

The refractive index measures the ratio of the speed of light in vacuum to speed of light in the oil under examination (Hee, 2011). For practical measurements, the scales of standard instruments indicate refractive indices with respect to air rather than vacuum (Guy, 2009). It is said to be related to the degree of saturation and the ratio of *cis/trans* double bonds and can furnish information on the oxidative damage (Hamilton *et al.,* 1986; Hee, 2011). The refractive index of oils again depends on the factors such as molecular weight, fatty acid chain length, degree of unsaturation and degree of conjugation (Shahidi, 2005; Ikya et al., 2013). According to Nielsen (1994); Ikya et al., (2013), the refractive index increases with increasing chain length and also with the number of double bonds present in the oil. Refractive index is a constant within certain limits for each type of oil or fat (Guy, 2009). It can therefore be used for rapid sorting of fats and oils which are suspected to be adulterated (Olaniyan and Oje, 2007; Munir *et al*, 2012) as well as one of the important physical characteristics

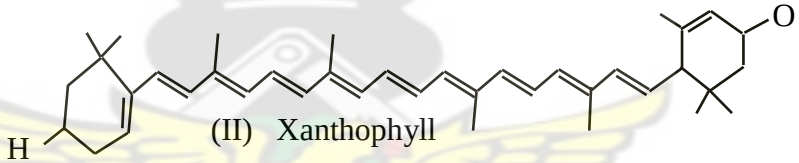
for purifying and identification of oils and fats (Munir *et al*, 2012). Triacylglycerols is found to have higher refractive indices than do their constituent free fatty acids as acknowledge by Shahidi (2005) and Ikya et al (2013).

2.9.1.2 Colour

The colour is a parameter that specifies the physical appearance of fat or oil. According to Omujal (2009), the colour of oil comes from natural colouring matters such as α- carotene (Figure 2.9 (I)), β-carotene, xanthophyll (Figure 2.9 (II)) and chlorophyll.



(I) α – carotene



(II) Xanthophyll

Figure 2.9: Structures of α- carotene and xanthophyll

As an extract of plant product, shea butter has being identified with characteristic colours. Researchers conducted so far reveal a variety of colours associated with the butter. The colour of shea butter by Asuquo *et al*, (2010) is milky – cream. Whitish yellow to yellow was identified as a typical colour for shea butter (Goreja, 2004; Moharram *et al*., 2006; Hee, 2011). However, Omujal (2009), give the colour of shea butter to be ranged from yellow-orange to red-orange. Orange, yellow to orange colour was also reported by Okullo et al, (2010).

2.9.1.3 Specific Gravity

Specific gravity which also referred to as relative density is the ratio of the density of substance compared to the density of water. It is an important physical property that is said to provide information on the identity of a sample as well as helps in detection of shea butter adulteration (Hee, 2011; Munir *et al*, 2012) of which density may increase or decrease (Hee, 2011). It is also said to furnish information for the shippers on the weight of shea butter from the given volume while exporting it in large volumes (Hamilton *et al*, 1986; Munir *et al*, 2012). Hee (2011) reported a consistent value of 0.9 as the refractive index in seven West African shea butter samples including Ghana. However, the African standard for shea butter quality ranged the refractive index from 0.89 - 0.93.

2.9.2 Chemical Parameters

The chemical parameters considered by most research for assessing the quality of natural oil of which shea butter is not an exception has been pointed out as free fatty acid, acid value, peroxide value, iodine value, ester value, saponification value and unsaponification value (Choe and Min, 2006). Besides, insoluble impurities and moisture are also important chemical indicators in shea butter quality characterization (McNally, 2008).

2.9.2.1 Free Fatty Acid and Acid Value

The free fatty acids are the fatty acid present in oil or fat which by lipase hydrolysis has not been neutralized (Guy, 2009). They are unattached fatty acids present in a fat (Sapna and Nirmali, 2009).The free fatty acids are said to be related to their acid values. The acid value is a parameter expressed as the number of milligrams of potassium hydroxide required to neutralize the free fatty acids contained in one gram

of fat or oil (Kardash and Tur'yan, 2004). It is expressed as twice the free fatty acid content in a given fat. According to Roger et al., (2010), the acid value is directly proportional to free fatty acid. Thus the lower the acid value of oil, the fewer free fatty acids it contains.

Low acid value suggests low levels of hydrolytic and lipolytic activities in the oils (Ikya et al, 2013). This is said to reduce the exposure of the fat or oil to the phenomenon of rancidification (Roger et al. 2010). It is also revealed that, acid value depends upon the degree of rancidity which is used as an index of freshness (Khan et al., 2006). It affords information for edibility of oils or fats as well as their suitability for industrial use. It is said to measure the extent of decomposition of the glycerides in the oil by the lipase.

Rancidity is accompanied by the formation of FFA and so acid value. FFA determination means the establishment of the quality and edibility of oil or fat (Onyeike and Oguike, 2003). It has been acknowledged further that the nutritional potential of a fat rely in some respects upon the quantity of free fatty acids which has been developed as far as vegetable oils act as the most common dietary lipid, it is important to ensure that the free fatty acid content should fall within the threshold limits of 0 0.6 and 10% (Codex Alimentairus Commission, 1993).

2.9.2.2 Moisture

Moisture is a chemical contaminant which is usually well mixed with oil. Presence of moisture in oil affects the quality of the oil. It has been reported that significant amount of moisture in oil support microbial growth (Alirezali et al., 2011). According to Hee (2011), the high level of moisture content in plant fats and oils usually result

in the increase of microbial load as well as lipid oxidation leading to rancidity. This will eventually reduce the shelf life of the fat and its corresponding product.

The low moisture content of shea butter suggested that the butter is of good quality (Olaniyan and Oje, 2007). Quainoo et al. (2013) reported the mean values of the moisture content of shea butter between a minimum of 5.23% to a maximum of value of 6.83% in selected districts within three Northern Regions of Ghana. This variation they said was attributed to vegetional difference of the regions and the extents of pressure on the shea trees. However, the African Standard for shea butter quality has given minimum moisture content of 0.05% to a maximum of 2.0%

2.9.2.3 Insoluble impurities

Insoluble impurities refer to dirt and other foreign materials in shea butter (Hamilton *et al*., 1986; Hee, 2011). It has been reported that some of these material are bonded to the butter via the machinery employed in the extraction of the butter. Others said they make their way into the butter through physical contact of the butter with the soil, ground as well as packaging materials.

As moisture content, the amount of insoluble impurities is identified as another important quality parameter which determines shea butter deterioration since metals can catalyse the oxidation of shea butter and thus decreases its market value (Hee, 2011).

2.9.2.4 Peroxide value

Peroxide value is the measures of milliequivalents of oxygen or hydroperoxides in 1 gram of fat or oil (Ikya et al, 2013). It is related to a valuable measure of oil quality as it provides an indication to the stability of the oil and the level of deterioration of fats.

It serves as an indicator of degradation of the long fatty chains through 'auto-oxidation' into peroxides that can later break down into other chemicals including malodorous ketones and aldehydes.

The parameter is said to be inversely related to the stability of oil or fat. The oil with higher stability is less exposed to rancidity. High peroxide value say (PV>10 meq kg^{-1}) is associated with the development of rancidity in fats and oils, which eventually limits their use in the food industry (Shahidi, 2005).

Peroxide value is said to be the most common determinant of lipid oxidation (Shahidi, 2005). Hydro peroxides under normal condition is remarked to have no flavour or odour of their own, they are however unstable and usually break down rapidly to other products such as aldehydes that have a strong, disagreeable flavour and scent.

2.9.2.5 Saponification Number

The saponification number is a measure of the alkali-reactive groups in fats and oil (Shahidi, 2005). It is defined as the number of milligrams (mg) KOH needed to hydrolyse or saponify completely 1.0 g of fat/oil (Onyeike and Oguike, 2003). The saponification value is said to be of interest only if the oil is going to be used for industrial purposes as it has no nutritional significance (Asiedu, 1989).

It is said to be important parameter in determining the suitability of oil or fat in soap making. A higher saponification value, suggest a large number of fatty acids especially lauric acid. This makes the oil a useful raw material for soap industries as well as the manufacture of lather shave creams (Eka, 1980). According to Nielsen,

(1994), the larger the saponification number, the better the soap-making ability of the oil/fat

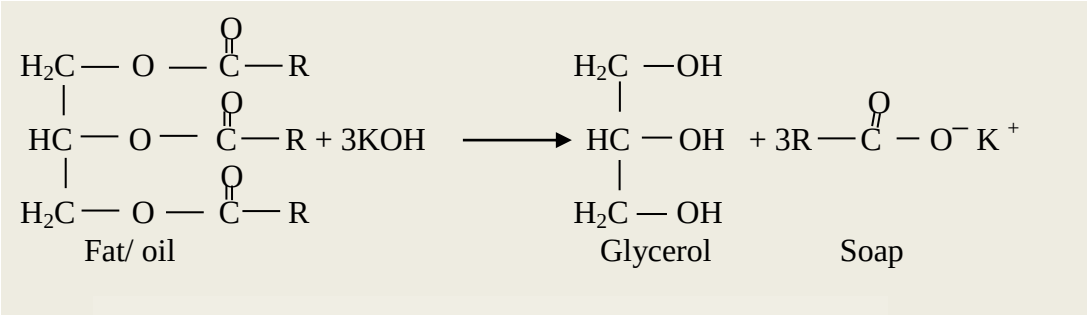


Figure 2.10: Saponification process

2.9.2.6 Unsaponifiable matter

Unsaponifiable matter refers to a large group of chemicals found in high concentrations in shea butter (usually 3- 12%) that are credited with giving shea butter its therapeutic properties. They are reported to include, antioxidants such as oil soluble tocopherols and water-soluble catechins. The triterpenes such as butyrospermol, phenols, sterols and other substances such as karitene and allantoin have also been identified as the constituencies of unsaponifiable matter associated with shea butter (SON, 2006).

According to Maranz et al, (2004), tocopherols are chemical parameters that are significant to nutrition and cosmetic properties of oils as they act as good anti-oxidants and also cause oxidative stability of the oil. The low level of tocopherols in fat can result in a serious decrease in the protective power of butter against auto-oxidation (Choe and Min, 2006). The West African shea butter has been reported to have over 800mg/100g of α-tocopherol (Maranz et al, 2004) which makes it stable and suitable for cosmetics.

2.9.2.7 Iodine Value

The iodine value (IV) is considered as the number of grams of iodine that could be added to 100 g of oil (AOAC, 1990; Shahidi, 2005). Iodine is not present in oils or fat but a simple chemical constant used to measure unsaturation or the average number of double bonds in an oil sample (Ikya et al., 2013). One of the chemistry of unsaturated organic compounds is the reactivity of their double bonds, especially their potential to undergo halogenation reactions to form halo-compounds. As the addition takes place at the double bond, measurement of the quantity of iodine absorbed represent the measure of the number of double bonds presents (Ihekoronye and Ngoddy, 1985).

Researchers have acknowledged that the iodine value serves as an index for assessing the tendency of the oil to go rancid (Eka, 1980; Amoo et al., 2004). It was remarked that, low iodine number signified the presence of few unsaturated bonds with increased number of saturated fatty acids and hence low susceptibility to oxidative rancidity of the oil or the fat (Onyeike and Oguike, 2003) and with the product prepared from the oil (Goh, 1994). On the other hand, high iodine values depict high content of polyunsaturated fatty acid in the product which exposes the oil and its product into high rate of deterioration through oxidation and rancidificatin.

Iodine value serve as an important medium where fats or oils can be identified as drying and non-drying. According to Pomeranz and Meloan (1984), fat or oil with the iodine values lower than one hundred (100) is regarded as non-drying. Those with the iodine value between one hundred (100) and one hundred and thirty (130), are considered as being semi-drying. Final oils or fats with iodine value between (130) and two hundred (200), are oil classified as drying.

2.9.2.8 Ester value

Ester value is another important parameter when oils quality characterizations are considered. It is defined as the number of milligrams of KOH required to combine with fatty acids present in the glyceride form in 1g of oils or fat. Or it is a measure of the actually amount of glyceride present in a sample of oil, which is saponafiable. It is said to measure the palatability of fats or oil. The higher the ester values the more the palatability of the oil (Dileesh, 2013). In the research of Asuquo (2008), the ester value of shea butter was found to be 183.4 which he said is in between that obtained for castor oil (174.09) and rubber seed oil (191.93), which are all vegetable oil. According to Dileesh (2013) and Lubrizol procedure (2013), the ester value can be determined by subtracting the acid value of oil from the saponification value of the corresponding oils.

Table 2.2: Existing Reports on Shea butter physicochemical properties

Parameter	**source**		
	Asuquo et al, (2010)	**Adomako (1985); Agyente and Kwame (2010)**	**Hee (2010)**
Colour	Milk-cream		Whitish yellow - yellow
Refractive index	1.6		1.463-1.465
Specific gravity	o.92		0.91± 0.00
Peroxide value	14.2		8.73±0.56 – 15.32± 5.71
Moisture content	10%		0.20±0.06 – 0.06± 0.02
Saponification value	185.20	179.6 – 190.0	
Iodine value	63.45	64.2	
Ester value	183.4		
Acid value	1.79	13.3	
Unsaponifiable matter	5.68%	7.3 – 9.0	2.21± 0.30 – 2.69± 0.44
Free fatty acids		6.8	1.46± 0.04 – 8.56±0.00
Insoluble impurities			0.12± 0.02 – 0.15 ± 0.01

2.10 Shea Butter Quality and Grading

The quality of shea butter according to many researches depends on the physical and chemical properties of the butter. However, the most indicative quality parameters of the butter, that is of interest for industrials use as well as for consumption considers the moisture content, the insoluble impurities, the free fatty acid (FFA) and the peroxide value (PV). Base on these parameters, shea butter has been classified into three grades by the Regional Technical Committee on African regional standard for unrefined shea butter (2006). The grading system specifies quality standard of butter suitable to be used in various industries. The **Grade 1** butter consists of those suitable to be used in cosmetic and pharmaceutical industries and for direct consumption. **Grade 2** shea butter are meant for food industries, for manufacturing confectionaries, chocolate, edible oil and for making margarine, **Grade 3** are used in making soap and can further be refined for direct consumption**. (See table** 2.4)

Table 2.3: Quality Characteristics and Grades of Unrefined Shea Butter

Parameter/Grade	**Grade 1**	**Grade 2**	**Grade 3**
	Min-max	**Min-max**	**Min-max**
Moisture content (%)	0 ─ 0.05	> 0.05 ─ 0.2	>0.2 ─ 2.0
Free fatty acids (%)	0 ─ 1.0	>1.0 ─ 3.0	>3.0 ─ 8.0
Peroxide value (meq/kg)	0 ─ 10.0	>10.0 ─15.0	>15.0 ─ 50.0
Insoluble impurities (%)	0 ─ 0.09	> 0.09 ─ 0.2	> 0.2 ─ 2.0

Source: Regional Technical Committee on Africa Regional Standard for Unrefined Shea Butter (2006), (Munir et al, 2012)

CHAPTER THREE

3.0 MATERIAS AND METHOD

3.1 Sampling

3.1.1 Soil Samples

Soil samples were collected from four districts in the Northern Region of Ghana. In each of the districts, three separate shea tree parklands were identified making a total of twelve shea tree parklands. Within each of the parklands (30) soil samples were randomly collected at depth of 15 to 30cm using an auger. The soil samples collected from each of the sampling points in each of the shea parklands were bulked together mixed thoroughly to obtain a homogenous mixture. Three (3) representative soil samples were then collected from each of the bulk mixture into plastic container well labeled, kept into ice chest, sent to laboratory and kept at standard temperature for analysis of the physical and the chemical properties. In all a total of thirty-six (36) soil samples; nine (9) from each of the selected districts were sent to the laboratory for the analysis.

3.1.2 Shea Nut Samples

Shea fruits were also collected in each of the identified shea tree parklands from the four districts. The nuts of the shea fruits were processed into shea butter. These were kept into well labeled plastic containers and transported to laboratory at standard temperature for the analysis of the physico-chemical properties. Also a total of thirty six shea butter samples; nine from each district were taken for laboratory analysis.

3.2 Geographical Description of the Study Site

The districts selected for the study include Yendi, Tolon, Savelugu- Nanton and Nanumba North as illustrated in **Figure 3.1**. Yendi Municipality is located in the eastern corridor of the Northern Region of the Republic of Ghana between latitude 90^o – 350^o North and 00^o – 300^o West and 00^o – 150^o East. The municipality shares boundaries with eight districts. These districts include; Saboba / Chereponi and Zabzugu /Tatale to the East, Nanumba North and East Gonja to the south, Mion to the West and finally Gushegu and Karaga to the North. The municipality has a landmass of 5350 sqkm with a mean annual rainfall of 1,125 mm. Temperature ranges between 21 °C- 36°C giving rise to high temperature. The vegetation is of the tree savannah type in areas not affected by settlements and farming activities. The degraded savannah type of vegetation is found around settlements and heavily cultivated areas. Economic trees in the Municipality include ubiquitous shea trees, dawadawa, mango and cashew. Basically sedimentary rocks like voltarian sandstone, shales and mudstones pre-dominate the municipality. The soils derived from the above parent materials range from laterite, ochrosols, sandy soils, alluvial soils and clay (MOLGRD, 2006).

Nanumba North District is located between latitudes 8.5^o N and 9.25^o N and longitude 0.57^o E and 0.5^o E in the eastern part of the Northern Region. It is shelled with Yendi Municipality to the North, East Gonja to the West and Nanumba South to the south. The district has a surface area with a landmass of 3,220 sqkm. Temperatures range from 29^o C to 41^oC with average annual rainfall of 1268 mm. Its vegetation is best described as Guinea Savannah with tall grass interspersed with drought and fire-resistant trees. Tree species found are the dawadawa, shea trees and baobab. The soils of the district are characteristically heavy and dark-coloured. Soil

types are the Savannah Ochrosols which are of alluvial-colluvial origin found mainly along major rivers and drainage courses and are located mid-south through to the north. They are well drained soils with the surface having loamy sand or sand-textured material with good water retention (MOLGRD, 2006).

Savelugu/Nanton Municipality is imprinted out of the then Western Dagomba District Council, which included Tolon/Kumbungu and Tamale Metropolitan Assembly. It shares boundaries with West Mamprusi in the North, Karaga to the East, Kumbungu in the West and Tamale Metropolitan Assembly to the South. The total land area of the municipality is 1790.70 sq. km. It receives an annual rainfall averaging 600 mm. Temperatures are usually high, averaging 34 ^{o}C. However, the temperature could rise as high as a maximum 42 ^{o}C and a minimum as low as 16^{o}C. The municipality is characterised by Guinea Savannah woodland. The common trees found in the area are drought resistant. Most of these are of economic value and serve as important means of livelihood especially for women. Notable among these are shea trees, and dawadawa trees. The Middle and Upper Voltaian sedimentary formation characterise the geology of the Municipality. The middle Voltaian covers the northern part comprises of sandstone, shale and siltstone. The Upper Voltaian covers the southern part of the Assembly and consists of shale and mudstone (MOLGRD, 2006).

Tolon district was created out of the erstwhile Western Dagomba District Council with its headquarters in Tamale. The district has Tolon as its capital. It shares boundaries to the North with West Mampursi, West Gonja to the West and Central Gonja to the South. Tamale Metropolitan and Savelugu/Nanton District share the Eastern boundaries with it. It covers a total landmass of 2,741 km^2 and lies between latitude 10-20 north and Longitude 10 to 50 west. The vegetation cover is basically

Guinea Savannah interspersed with short drought resistant trees and grassland. The soils are generally of the sandy loam type except in the low lands where alluvial deposits are found. The major economic tree species in the district include; shea nut, dawadawa and mangos (MOLGRD, 2006).

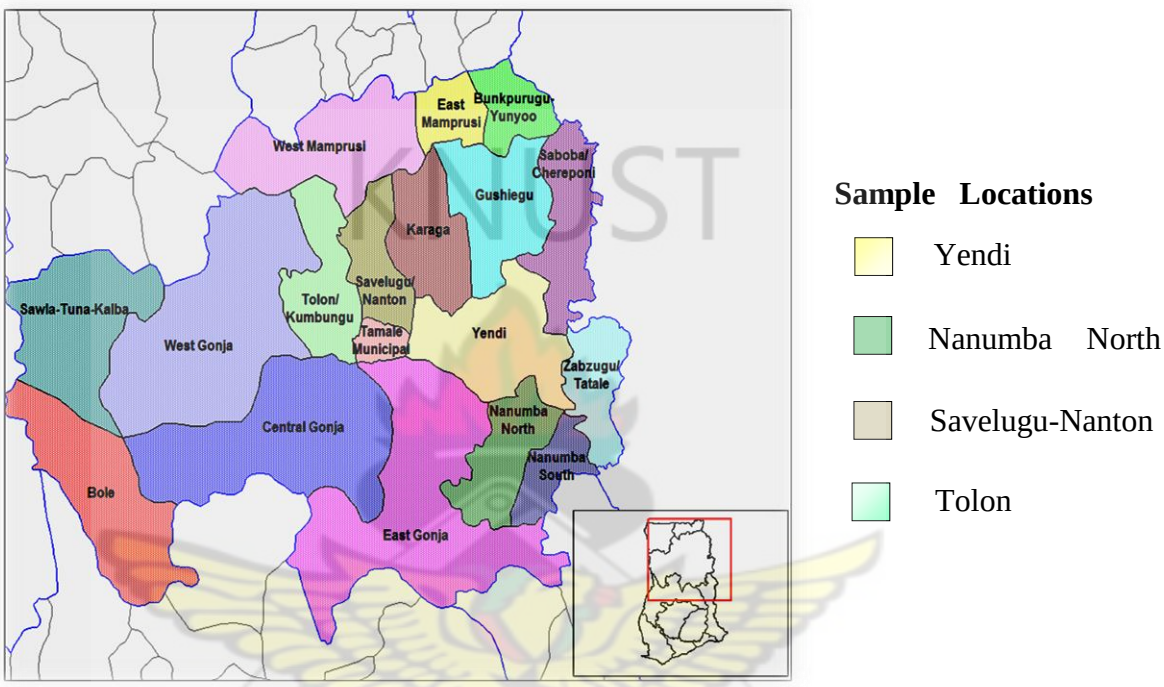


Figure 3.1: A Map Showing the Districts in the Northern Region of Ghana Where Samples Were Collected

Source: http://en.wikipedia.org/wiki/Districtso of Ghana

Table 3.1: Sample collection sites and number of samples collected

District	Sampling Site	Number of Samples	
		Soil	Shea butter
Yendi	Yendi	9	9
Nanumba- North	Bimbilla	9	9
Savelugu-Nanton	Savalugu	9	9
Tolon	Tolon	9	9
Total		**36**	**36**

3.3 Analysis of Soil Physico-Chemical Parameters

The laboratory analysis of the physico-chemical properties of the soil were carried out at Savana Agricultural Research Institute, Nyankpala in the Northern Region of Ghana. The soil physico-chemical properties that were considered in this research include the pH and the particle size distribution, the level of nitrogen and organic carbon content, available phosphorus as well as available potassium and cation exchange capacity.

3.3.1 Pre-Treatment of Soil for Physico-Chemical Analysis

The soil samples were air-dried by placing them in a shallow tray in well ventilated area. Clay clods were broken and soil lumps crushed such that the gravel, roots and organic residues become separated. The crushed soil samples were sieved through a 2 mm sieve to a very fine soil samples

3.3.2 Determination of Soil pH

Ten grams (10g) air- dried soil sample was weighed into a 100 ml beaker. Twenty-five millilitre (25ml) distilled water was added and the suspension stirred vigorously for 20 minutes. The suspension was allowed to stand for about 30 minute for the suspended clay to settle out from the suspension. The pH meter was calibrated with pH buffer 4, 7 and 11. The electrode of the pH meter was inserted into the partly settled suspension. The pH value was then read and recorded immediately (Brian, 1997).

3.3.3 Determination of Soil Particle Size Distribution

Hydrometer method as prescribed by Brian, (1997) was used for this analysis. Fifty-one grams (51.0g) air – dried soil sample was weighed into a one – litre screw lid

shaking bottle. 100 ml distilled water was added and the mixture swirled thoroughly to wet the soil. Twenty millitre (20 ml) of 30 % H_2O_2 was added in order to destroy the soil organic matter and hence free the individual classes of soil. 50 ml of 5 % sodium hexametaphosphate solution was added. This was followed by the addition of three drops of amyl alcohol and gently swirled to minimize foaming. The sample was shaken on a mechanical shaker for 2 hours and the content transferred into a 1000 ml sedimentation cylinder. Distil water was added washings all soil particles to the sedimentation tube and was made up to the 1000 ml mark with distilled water. First hydrometer reading and the temperature were recorded after 40 seconds. The sample was allowed to rest undisturbed for 2 hours. The second hydrometer and temperature readings were recorded again after this duration. The formula below was used to calculate the percent sand, silt and clay and hence the textural class.

$$\text{Sand (\%)} = 100 - [(R_{40S} - R_L) \times (100/\text{oven-dried soil wt.in g})]$$

$$\text{Clay (\%)} = (R_{2H} - R_L) \times (100/\text{oven-dried soil wt. in g})$$

$$\text{Silt (\%)} = 100 - (\text{sand \%} + \text{clay \%})$$

Where R_L = scale reading at the upper edge of the meniscus on the stem of the hydrometer.

R_{40s} = 1st Hydrometer reading at 40 seconds

R_{2H} = 2nd Hydrometer reading at 2 hours

3.3.4 Determination of Phosphorous

The available phosphorus was determined according to the procedure adopted by Bray and Kurtz (1945). Five grams (5 g) of the soil sample was weighted into a 50

ml shaking bottle and 35 ml of Bray1 P extracting solution added. The content was shaken on a mechanical shaker for 10 minutes. It was then filtered into a 100 ml conical flask using whatman No. 42 filter paper. Five millitre (5ml) of the filtrate was pipette into a 25 ml volumetric flask and 1.0 ml of molybdate reagent added after which 1.0 ml of the dilute reducing agent was added to develop a blue colour solution. The content was topped up with distilled water to the 25 ml mark. This was swirled for the content to mix well and the solution allowed to stand for 15 minutes for colour to develop. The absorbance was then measured at 600 nm wavelength on a spectrophotometer. The level of phosphorus was then calculated using the formula below

$$\text{Available phosphorus (mg/Kg)} = \frac{c \times 14}{ADW}$$

Where c = phosphorus concentration from a calibration chart

ADW = Air dry soil sample weight (g)

14 = dilution factor

3.3.5 Organic Carbon Determination

The method employed for this analysis was based on the procedure used by Walkley and Black (1935). Under this method, 2.0 g of soil sample was weighed out into a 500 ml Erlenmeyer flask. Exactly 10 ml of 1.0 N potassium dichromate solution was added, followed by 20 ml of concentrated H_2SO_4. The mixture was swirled such that the solution was in contact with all the particles of the soil. The flask and content were allowed to cool on an asbestos sheet for 30 minutes. 200 ml of distilled water and 10 ml of orthorphosphoric acid were added. This was followed by the addition of 2.0 ml of 10 ml of diphenylamine indicator. This was titrated with 10 N ferrous

sulphate solution until the colour changed to blue and then to a green end – point. The titre value was recorded and corrected for the blank solution (> 10.5). The organic carbon was calculated from the relation shown below.

% organic C in soil = (m. e. $K_2Cr_2O_7$– m. e. $FeSO_4$) x 0. 003 x f x 100 wt. of soil

Where m. e. = milli equivalent = Normality of solution x ml of soln. used

0.003 = m. e. wt. of C

f = correction factor = 1. 33

3.3.6 The Procedure for Determining the Cation Exchange Capacity (CEC)

Sodium Acetate method was employed for this analysis. Five grams (5g) of the soil sample was accurately weighed and transferred into a 50-ml centrifuge tube. Twenty-five milliliter (25ml) of 1.0M $CH_3CHOONa$ solution was added. The content was shaken in a mechanical shaker for 5 minutes. This was centrifuged at 2000 rpm for 5 minutes. The liquid was decanted off and the extraction process repeated for three more times. The sample was washed with the same extraction process using isopropyl alcohol followed by the use of ammonium acetate solution. The decant was collected into a 100-ml volumetric flask fitted with a funnel and filter paper. This was made up to volume with ammonium acetate solution. The sodium concentration was estimated by flame photometer and the result expressed in meq/100g of the dry soil. The measured Na expressed in meq/100g of soil is actually the cation exchange capacity of the soil (Motsara and Roy, 2008)

3.6.7 Nitrogen Analysis.

The Kjeldahl method by AOAC (1997) was used for the analysis. The method was partitioned into three main steps. It proceeds with digestion of the sample in concentrated sulphuric acid. The resulting solution from the digestion was distilled and the distillate titrated against an acid. In the case of this analysis, 10 g of air dried soil sample was weighted into a 500 ml long – necked kjeldahl flask. 10 ml distilled water was added and the content was allowed to stand for 10 minutes to moisten. A one spatula full of kjeldahl catalyst was then added. This was followed by the addition of 30 ml conc. H_2SO_4. This was digested until clear and colourless solution was obtained. The flask was allowed to cool. The solution obtained was decanted into a 100 ml volumetric flask and made up to the mark with distilled water. 10 ml of the solution was pipetted and transferred into the kjeldahl distillation apparatus. 20ml of 40% NaOH was added and the distillate collected over 10 ml of 4% Boric acid and three (3) drops of mixed indicator in a 500 ml conical flask for 4 minutes. The distillate was titrated with 0.l N HCl till the blue colour changed to grey and then suddenly flashed to pink at the end point. A blank determination was performed. The percentage nitrogen in the soil sample was calculated from the relation

$$\% \text{ Nitrogen} = \frac{14 \times (A - B) \times N}{1000 ms(g)} \times 100$$

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

ms = weight of soil sample (g)

3.3.8 Analysis of Potassium in the Soil Sample

The potassium content was determined using ammonium acetate method as prescribed by Toth and Prince (1949). Under this, 10 g of 2 mm sieved air dried soil sample was weighed into a 50ml centrifuge tube. 25ml of 1.0M NH_4OAc was added and content shake in a mechanical shaker at 200 rpm for 5 minutes. The suspension was filtered through Whatman No.2 filter paper and the filtrate collected into 100 ml volumetric flask and was made up to the mark. The amount of the potassium was then determined by flame photometer at a wavelength of 766 nm. From the calibration curve prepared from potassium standard, the content of the potassium was determined.

3.4 Analysis of Shea butter Physico-Chemical Properties

The butter was extracted by the traditional method as prescribed in fig 2.6. The physicochemical properties of the shea butter were analyzed in the laboratory of the Shea butter processing plant at Buipe in the Central Gonja District of Northern Region of Ghana and Food Research Institute in Accra.

The physicochemical properties that were considered for analysis include; pH, fat content and colour, moisture content, insoluble impurities and specific gravity (SG). Other properties such as the free fatty acid (FFA), iodine value, peroxide value and sponification value, ester value as well as unsaponification value were also considered.

3.4.1 Determination of pH of The Shea butter

The HI electronic meter as adopted and used by Akpan et al (2005) was employed for this analysis. Under this method, two grams (2 g) of the shea butter sample was

weighted into a clean dry 25 ml beaker and 13 ml of hot distilled water added. The content was stirred slowly and then cooled in a coldwater bath to 25 °C. The pH electrode was calibrated with buffer solution of 4, 7 and 11and then immersed into the sample. The pH value was read and recorded.

3.4.2 Determination of Fat Content of the Shea butter

The fat content of the butter was determined by the method recommend by Sergers (1990). Soxtherm analyser was used for the analysis. For this analysis, an empty extraction beaker was weighted. Dried shea nut sample was crushed and 5g of it was weighed in an extraction thimble placed in a beaker on analytical balance. The thimble was fixed in a thimble holder and covered with cotton wool. This was placed in the extraction beaker and 100 ml hexane added. It was then fit in the soxtherm machine, which was allowed to run for the fat to be extracted. The extraction beaker and its content were placed in an oven to dry off the hexane. This was allowed to cool and the beaker with the butter weighted. The percentage fat content of the shea nut was then calculated from the formula

$$\text{Percentage fat} = \{(M2 - M1)/ W\} \times 100$$

Where; M1= weight of the empty beaker

M2= weight of beaker with shea butter

W= weight of crushed shea nut

3.4.3 Shea butter Colour Determination

The Shea butter sample was melted at 30 ^{o}C in water bath. It was then placed in a cuvet and the colour measured using Tintometer a model recommended by AOAC (1997).

3.4.4 Determination of Specific Gravity of the shea butter

The SG of the shea butter was determined using the method as proposed by Akpan et al. (2005). Base on this, a specific gravity bottle was cleaned with acetone and dried in an oven at 60 ^{o}C. The empty bottle was weighed, filled with the butter sample and the weight taken again. The sheabutter sample was removed from the bottle. The bottle was properly washed and filled with distilled water. The weight of bottle and the water were taken. The specific gravity was then calculated using the formula shown below;

$$\text{Specific Gravity} = \frac{W_o - W}{W_1 - W} .$$

Where, W = Weight of empty bottle (g), Wo = weight of the bottle and oil content (g), W1 =Weight of bottle and water content (g).

3.4.5 Determination of Refractive Index of Shea butter

The refractive index was determined using Abbey refractometer, a procedure recommended by AOCA (1997). By this method, the glass prism of the refractometer was thoroughly cleaned with alcohol to remove the dust. A small quantity of the shea butter sample was placed on the lower prism and smeared. The prism was closed with the other covering prism and the light source of the refractometer switched on while viewing through the telescope. The coarse adjustment knob was rotated for the black

shadow to appear central in the cross wire indicator. While viewing through the telescope, the fine knob was adjusted until a rainbow-coloured fringe which appeared on the black dividing line disappeared. The coarse knob was rotated to produce fine adjustment which makes the black shadow to appear exactly central in the cross wire indicator. The reading under the telescope and that of the fine adjustment knob were noted. This value was then divided by 10,000, and was then added to the value obtained through the telescope to give the value of the refractive index of the butter.

3.4.6 Determination of the Moisture Content of the Shea butter

Twenty grams (20 g) of cleaned shea butter sample was weighed and dried in an oven at 50 °C. After every 1 hour, the sample was removed from the oven and placed in the desiccator for 30 minutes to cool. It was then removed and weighed (*Akpan et al., 2005*). The percentage moisture in the butter was then calculated from:

$$\text{Moisture} = \frac{100(W_1 - W_2)}{W_1}\%$$

where; W1 = Original weight of sample before drying (g), W2 = Weight of sample after drying (g)

3.4.7 Determination of Insoluble Impurities of the Shea butter

The insoluble impurities were determined using the IUPAC 2.604 method as described in Paquot *et al*, (1987). By this method, 10 ml capacity gastight syringe was filled with 4 ml of melted shea butter sample and the syringe was then weighed. A filter and the filter paper were weighed and then placed in a filter holder and attached to the tip of the syringe. Pressure was applied on the syringe to cause the Shea butter sample to pass through the filter. The filter and the filter paper in the holder were washed with 30 ml of hexane to remove the shea butter from the device.

The filter paper was then dried in an oven at the temperature of 100 °C for 10 minutes to evaporate all solvent and then weighed. The insoluble impurities that remained in the filter paper were then calculated from the formula below:

$$\text{Insoluble Impurity (\%)} = \frac{m_2 - m_1}{w} \times 100$$

Where: w is the weight of the shea butter, m_1 is the mass, of the filter paper and the filter, m_2 is the mass of the filter paper with the insoluble impurities and the filter.

3.4.8 Determination of Free Fatty Acid

The free fatty acid was determined using the standard method in Akpan et al., (2005). Two grams (2g) of the shea butter sample was accurately weighed into a 250 ml conical flask with a glass stopper. Fifty (50ml) of hot neutralised isopropyl alcohol (IPA) solution was added. This followed with the addition of few drop of phenolphthalein. The content was titrated against 0.1 N NaOH with vigorous shaking until a permanent pink colour was obtained. The free fatty acid (FFA) was calculated as follows:

$$\text{\% FFA} = \frac{vol.of\ 0.1N NaOH \times 0.028}{WB} \times 100$$

Where WB = weight of shea butter

3.4.9 Determination of Acid Value

The acid value was determined as being equivalent to twice the FFA as modified from the expression 4 of Akpan et al., (2005).

That is: $\%\text{Acid value} = 2 \times \%FFA$

3.4.10 Saponification value Determination

The Saponification value was determined using titremetric method discussed by Pearson (1981). In this procedure, 2 grams of the shea butter samples was accurately weighed into a conical flask. 25 ml ethanol potassium hydroxide was added and the solution refluxed for 2 h with intermittent shaking. 1 ml phenolphthalein indicator was added and the content titrated with 0.5N HCl to obtain a colour change from pink to colourless. Blank determination was conducted alongside those of the sample test with the same chemical reagents minus the butter sample. The saponification value was calculated from the relation:

$$\text{Saponification Value} = \frac{(V_0 - V_1)C \times 56.1}{m}$$

where 56.1 is equivalent weight of KOH, V_o is the volume in ml of standard HCl solution used for the blank test, V_1 is the volume in ml of the standard HCl solution used for sample, C is the exact concentration of the standard HCl (0.5 N) solution and m is the mass in gram of the shea butter sample.

3.4.11 Determination of Unsaponifiable Matter

The unsaponifiable matter of the shea butter sample was determined according to IUPAC 2.401diethyl ether method (Paquot *et al*, 1987). Two grams (2 g) of the shea butter sample was refluxed gently for 1 hour with 20 ml of potassium hydroxide ethanolic solution (6%, w/v). The sample was diluted with 50 ml of distilled water and unsaponifiable matters were extracted with 50 ml of diethyl ether for 3 times. The ethereal extract recovered was then washed with 20 ml of distilled water for 3 times. It was again washed with 20 ml of 0.5N potassium hydroxide and 20 ml of distilled water. The washing process was repeated until the collected water from the washing gave no pink colour upon the addition of a drop of phenolphthalein solution. This was

then evaporated in a round bottom flask with ground joint which was previously dried and weighed to the nearest 0.0001 g by distillation. After the distillation, 5 ml of acetone was added to the flask and the volatile solvent was evaporated through a gentle current of air, resulting in creamy substances on the bottom of the flask. The flask was then dried in the oven at 60 °C and the residue was weighed based on the weight of the flask with the residue and the weight of the flask. After weighing the residue, 4 ml of diethyl ether was added in the flask to dissolve the residue, followed by the addition of 10 ml of neutralized ethanol. The resultant solution was stirred for 10 minutes and additional 2 drops of phenolphthalein solution was added to it. The solution was then titrated with 0.1 N ethanolic potassium hydroxide solutions until the color turned to pink. The amount of unsaponifiables (%) was calculated by the following formula:

$$\%\ \text{unsaponifiable} = \frac{100 \times (ml - 0.28VT)}{m}$$

where, m is the mass, in g, of the soil sample, m1 is the mass, in g, of the residue, V is the number of ml of the standardized potassium hydroxide solution used, and T is the exact normality of the potassium hydroxide solution used.

3.4.12 Peroxide Value Determination

Peroxide value was determined according to AOCS Official Method Cd 8-53(2003) that was used in Atinafu and Bedemo, (2011). By this method, 5g of the shea butter sample was accurately weighed into 250 ml conical flask. 30 ml of solvent mixture of acetic acid/cyclo-hexane in the ratio of 3:2 respectively was added and the flask shaken to completely dissolve the butter. 0.5 ml of freshly prepared saturated potassium iodide (KI) solution was added to the solution and allowed to stand for 1minute. Thereafter, 30ml distilled water was added followed by 0.5 ml starch

solution. The content was titrated with 0.01N $Na_2S_2O_3$ solution until the dark-blue colour disappeared. Blank titration was also conducted alongside the sample test. The peroxide was calculated from the relation:

$$\text{Peroxide value} = \frac{10 \times (V_1 - V_2)}{m}$$

where: V_1 volume of $Na_2S_2O_3$ solution in ml for determination of test sample, V_2 volume of $Na_2S_2O_3$ solution in ml for determination of blank and m is mass of shea butter sample.

3.4.13 Iodine Value Determination

Iodine value of the sample was determined using the official method described by AOAC (1997). The shea butter samples were melted at 60-70 ^oC in an oven mixed thoroughly filtered and dried for two minutes. 0.5g of the dried sample was accurately weighted into a 250ml Erlenmeyer flask and 20ml of cyclohexane/acetic acid (1:1) mixture added. Afterwards, 25ml of Wij's solution was added. This was covered with aluminium foil and placed in the dark for 1 hour. 20 ml of freshly prepared 10% KI solution and 100ml distilled water were then added. The content was titrated against 0.1N $Na_2S_2O_3$ solution until the yellow colour of the iodine almost disappeared. Starch indicator solution was added and the titration was continued until the solution changed from blue to colourless. Blank test was carried out simultaneously under the same condition without the test sample. The iodine value was therefore calculated from the expression:

$$\text{Iodine value} = \frac{12.69 \times N(V_2 - V_1)}{W}$$

where: N is the exact normality of thiosulphate solution used; V_2 is the volume of sodium thiosulphate solution used for blank. V_1 is the volume of sodium thiosulphate solution used for sample. W is the sample weight

3.4.14 Determination of Ester Value

The ester value was determined using the procedure described by Dileesh (2013), and Lubrizol procedure, 2013. By this method, ester values were determined using the relation:

Ester value = acid value – saponification value

CHAPTER FOUR

4.0 RESULT AND DISCUSSION

4.1 RESULT ANALYSIS

The data generated from the analysis of soil and butter samples were processed and presented in tables and graphs to offer explanations to the results of the research. There were significant differences between the physical and chemical properties of both soil and butter samples from four districts of Northern Ghana. It showed that soil properties had significant correlation with fat content of shea nuts. Thus soil properties have showed some influence on the butter content of shea nuts but not much on the other characteristics qualities of the butter.

4.1.1 Soil Physical Properties

4.1.1.1 Percentage Sandy Soil

Analysis of the soil samples from four districts of the Northern region of Ghana shows that the sandy soil dominates all the other soils present in the shea tree growing district. As shown in **Figure 4.1,** the sandy soil is the common highest in all the districts with the highest at the Savelugu (66.60%) district but least common at the Tolon district (52.04%). The difference by percentage of sandy soil across the four districts was significant (see appendix III).

4.1.1.2 Percentage Silt

Silt was highest at the Tolon District (38.65%) and least at the Nanumba North District (26.69%) as shown in Figure 4.1. Silt soil is the second most common soil in the shea butter producing communities (Figure 1). The percentage silt was

significantly different across the shea butter producing communities of the Northern region (see appendix III).

4.1.1.3 Percentage Clayey Soil

The least common soil in shea butter producing communities according to this study is the clayey soil **(Figure 4.1).** Clayey soil was highest again Tolon District (9.31%) and least at the Savelugu-Nanton District (4.73%). The difference among percentage clayey soil across the shea districts was however significant (see appendix III).

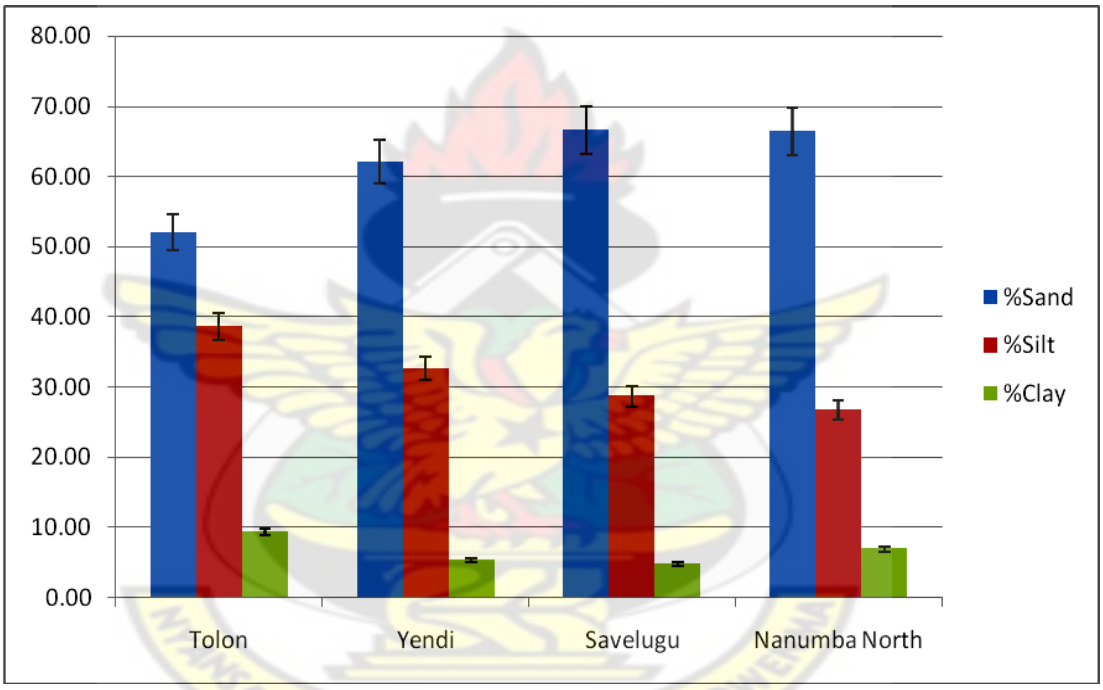


Figure 4.1: Percentage soil physical properties of four Districts of Northern Ghana

4.1.2 Chemical Properties of Soil

4.1.2.1 Percentage Organic Carbon (%OC)

The highest organic carbon content was recorded at the Yendi Municipality and the least value at Tolon district **(Table 4.1).**There were significant differences ($P \leq 0.05$) in the organic carbon content of soil across the four districts **(Table4.1).** The specific

differences in the organic carbon content among the district using fisher LSD were also significant.

4.1.2.2 Percentage Organic Matter (%OM)

The OM content presented in **Table 4.1** showed significantly different ($p \leq 0.05$) across the four shea butter processing districts. The least of 1.46% was recorded at the Tolon district and a higher of 2.04% at the Yendi Municipality. The OM content was also statistically different ($p \leq 0.05$) with the Fishers least significant difference (LSD) analysis.

4.1.2.3 Percentage Cation Exchange Content (%CEC)

The CEC content as presented in **Table 4.1,** recorded a least value of 6.25% at Yendi Municipality and the highest of 7.03% at the Tolon district. There were significantly different ($p \leq 0.05$) across the four shea butter processing districts. The CEC content was also statistically different ($p \leq 0.05$) with the Fishers least significant difference (LSD) analysis.

4.1.2.4 Percentage Total Nitrogen (%TN)

The statistical analysis of the soil Total Nitrogen indicated that the percentage Total Nitrogen were all different ($p \leq 0.05$) across the various districts. The Total nitrogen ranged were 0.08 for the Tolon District and 0.10% for the other three districts. The Total nitrogen from three districts had uniform measurement as shown in **Table 4.1**. Thus, percentage total nitrogen from the Yendi Municipality, the Savelugu and the Nanumba North districts were generally the same by the Fisher's LSD.

4.1.2.5 Percentage Phosphorus Content (%P)

The Phosphorus content presented in **Table 4.1** was significantly different ($p \leq 0.05$) across the four shea butter processing districts. The least recorded value of 2.49% was recorded at the Tolon and the highest of 4.31% at the Savelugu-Nanton district. The Phosphorus content was also statistically different ($p \leq 0.05$) with the Fishers least significant difference (LSD) analysis

4.1.2.6 Percentage Exchange Potassium (%EP)

The statistical analysis of the soil exchange potassium indicated that the percentage exchange potassium were all different ($p \leq 0.05$) across the various districts. The exchange potassium values ranged from 0.16 at the Yendi Municipality to 0.24% at the Savelugu-Nantong district. The exchange potassium from the four districts had non-uniform measurement as shown in **Table 4.1.** Thus, percentage exchange potassium from the four districts was not statistically the same by the Fisher's LSD.

Table 4.1: Mean Percentage Soil Chemical Properties across Four Shea Districts in the Northern Region of Ghana

District	% OC	% OM	%CEC	% Total Nitrogen	% Phosphorus	% Exchange potassium
Tolon	0.85	1.46	7.03	0.08[a]	2.49	0.23
Yendi	1.18	2.04	6.25	0.10[b]	2.89	0.16
S-N	1.08	1.86	6.31	0.10[b]	4.31	0.24
NN	1.01	1.75	6.83	0.10[b]	2.94	0.17
Mean value	1.03	1.78	6.61	0.10	3.16	0.20
p-value	0.001	0.001	0.002	0.001	0.001	0.001

OC means organic carbon, OM means organic matter, and CEC means cation exchange capacity. S-N (Savelugu –Nanton), NN (Nanumba North)

4.2 Physical and Chemical Properties of Shea Butter

4.2.1 Physical Properties of Shea butter

4.2.1.1 Yellow Colour Intensity

The yellow colour intensity presented in **Table 4.2** varied significantly among samples across the four districts. The yellow colour intensity ranged from a minimum of 33.0% in the Savelugu-Nanton district and a maximum value of 70% at the Yendi Municipality. The yellow colour intensity was statistically different ($p \leq 0.05$) across the districts when further comparisons were made using the Fishers LSD.

4.2.1.2 Moisture Content

The moisture content presented in **Table 4.2** was significantly different ($p \leq 0.05$) across the four shea butter processing districts. The least of 4.7% was recorded at the Nanumba-North district and the highest of 6.7% at the Yendi Municipality. The moisture content was also statistically different ($p \leq 0.05$) with the Fishers least significant difference (LSD) analysis.

4.2.1.3 Fats

The fat content was significantly ($p \leq 0.05$) different from one district to the other as elaborated in **Table 4.2** below. The fat content of the shea butter ranged from a lower of 48.24% at Tolon to a higher of 49.37% at Yendi Municipality. The mean value of the fat content across the four districts is 48.69%.

4.2.1.4 The Red Colour Intensity

There were significant differences ($p \leq 0.05$) in the red colour intensity of shea butter across the four districts (**Table 4.2).** The specific differences in the red colour intensity among shea butter samples across the four districts using the Fishers LSD were significant. There was about double as much red colour intensity in the butter from the Yendi Municipality as there was in the butter from the Savelugu district (**Table 4.2).**

4.2.1.5 Insoluble Impurities

The statistical analysis of the shea butter impurities indicated that the impurities were not different ($p \geq 0.05$) across the various districts. The butter impurities ranged from 0.03 at Nanumba North District to 0.27% at Savelugu district. The shea butter from all four districts had uniform specific gravity (density) as shown in **Table 4.2**.

Table 4.2: Mean Percentage Shea Butter Physical Properties

District	**RI**	**SG**	**% Red**	**% Yellow**	**% Fats**	**% Moisture**	**% Impurities**
Tolon	1.47	0.91	2.35	60.00	48.24	5.31	0.14
Yendi	1.47	0.91	4.00	70.00	49.37	6.65	0.09
S-N	1.47	0.91	2.15	33.00	48.78	4.81	0.27
N-N	1.47	0.91	3.55	59.00	48.38	4.70	0.03
Mean value	1.47	0.91	3.01	55.50	48.69	5.37	0.13
p-value	*	*	0.007	0.006	0.001	0.001	0.081

* the means were all of the same value, SG stands for specific gravity, RI refractive index, savelugu-Nanton (S-N), Nanumba – North (NN)

4.2.2 Chemical Properties of Shea Butter

The chemical properties of shea butter tested under this study were: free fatty acids (FFA), acid value (AV), butter pH, peroxide value (PV), iodine value (IV), saponification value (SV), ester value (EV) and unsaponifiable value (USV). Free Fatty Acid (FFA) was high (7.67) in the shea butter obtained from the Yendi

Municipality than any other district in the study in the Northern region and least (3.49) at Savelugu-Nantong district (**Table 4.3**). The mean FFA value was 5.37 and the result was significantly ($p \leq 0.05$) different across the four shea districts of Ghana (**Table 4.3**). The Acid Value (AV) like the FFA ranged from the least value of 6.97 at Savelugu-Nantong to a maximum value of 15.35 at the Yendi Municipality. The AV were all significantly different ($p \leq 0.05$) across the Shea districts of Ghana. The mean value for AV was 10.76.

The shea butter pH was significantly different ($P \leq 0.05$) as shown in **Table 4.3.** The highest pH value was recorded at Nanumba North District (5.80) and the least at the Yendi Municipality (4.70). The mean pH value recorded for shea butter across the four research centre is 5.18. The measure for peroxide value (PV) ranged from 7.10 to 9.49 at Nanumba North and Yendi respectively. The mean PV for the four research areas was 8.06. The PV was significantly different ($p \leq 0.05$) across the four districts.

The iodine value (IV) and the ester value (EV) were both significantly different ($p \leq 0.05$) as shown in **Table 4.3.**

The IV and the EV were respectively highest at Yendi (63.73) and Savelugu (178.55) and least at Savelugu (55.06) and Yendi (165.91). The mean values for IV and EV were 59.44 and 174.10 respectively.

The Saponification (SV) and Unsaponifiable values (USV) were both highest (187.07 and 5.27 respectively) in Nanumba North District. The least recorded values for SV and USV (181.59 and 3.34 respectively) were also found in the Yendi Municipality. This is shown in **Table 4.3.**

Table 4.3: Shea butter chemical properties (mg/Kg)

District	F FA	AV	Butter pH	PV	I V	E V	SV	USV
Tolon	5.31	10.61	5.40	9.29	60.66	174.97	185.57	3.60
Yendi	7.67	15.35	4.70	9.49	63.73	165.91	181.59	3.34
S-N	3.49	6.97	4.80	6.35	55.06	178.55	185.75	4.26
NN	5.05	10.11	5.80	7.10	58.32	176.96	187.07	5.27
Mean value	5.37	10.76	5.18	8.06	59.44	174.10	185.00	4.12
p-value	0.008	0.008	0.001	0.002	0.001	0.001	0.001	0.002

4.3 Shea Butter Quality Characteristics in the Northern Region of Ghana

The qualities of shea butter extracted from four districts in the Northern Region of Ghana are presented in **Figure 4.2.** They were measured based on the standard developed by the Technical committee of West Africa Regional quality Standard for unrefined shea butter (2006). In this grading system, the moisture content, free fatty acids, the peroxide value and the insoluble impurities are considered as the key indicators for measuring the quality of shea butter. (see Table 2.3).

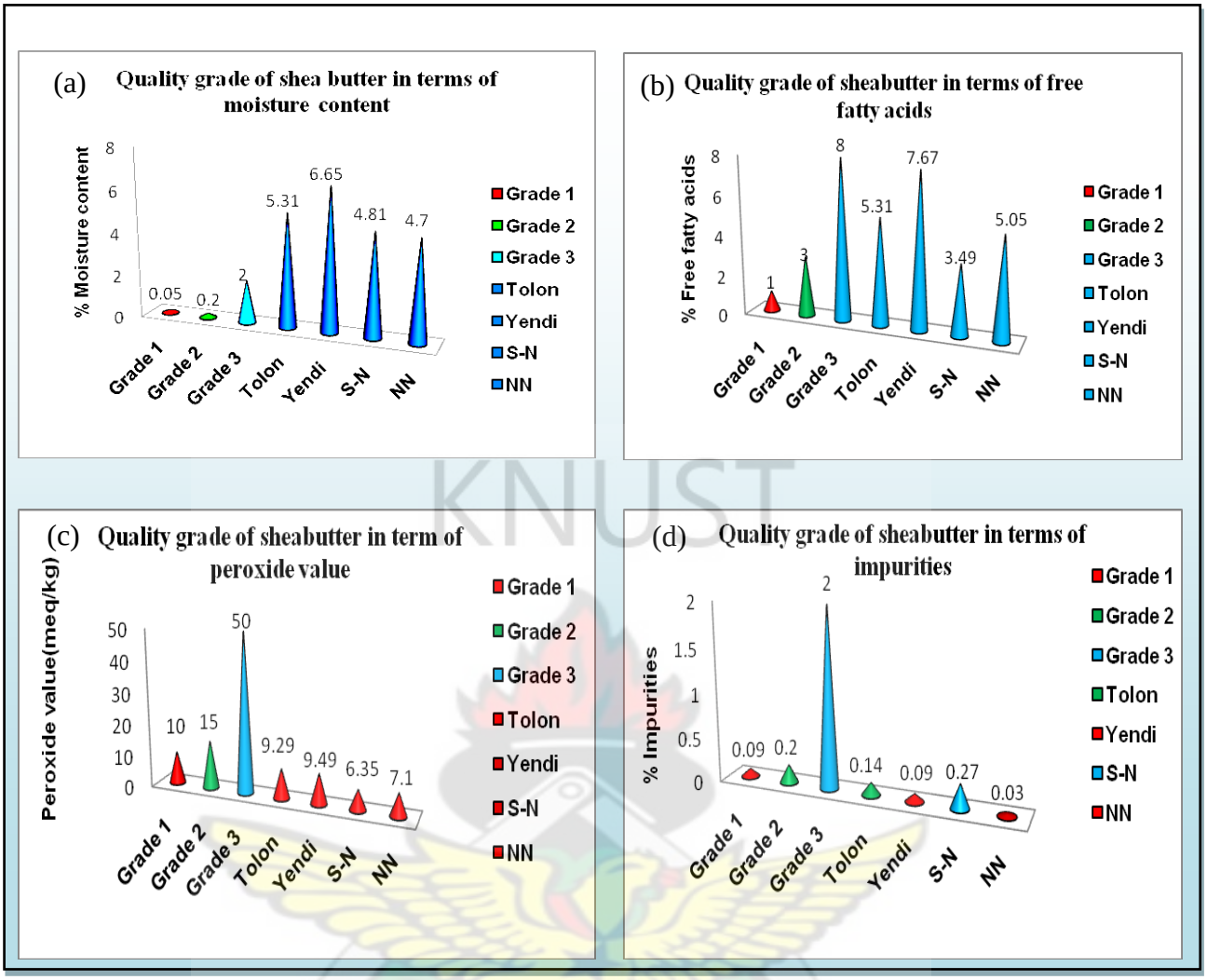


Figure 4.2: Shea butter quality grades in the Northern Region of Ghana

The first three bars in each of the graphs in **Figures 4.2** represent the range of reference standard grades 1, 2, and 3 shea butters. The other bars measured the qualities of the butters in the study districts in relation to the grades. The red, green and the light blue colours depict the grade 1, 2 and 3 respectively.

The moisture content of all the shea butter extracted from the districts compared to the reference standard was relatively high (see figure 4.2 a)**,** thus the qualities of the butter in the districts could not be specified under any of the quality grades. Even though, there is a significant difference ($p<0.05$) (table 4.2) between the levels of free fatty acids in the shea butter extracted across the districts, they were relatively low

enough to place all shea butter extracted from the districts under grade 3.(see figure 4.2b). The peroxide values obtained from extracted shea butter in the districts pushed all the shea butters under grade 1. The insoluble impurities of the shea butters in the four study areas by statistical analysis presented no significant different ($p > 0.05$) across the four districts (table 4.2). However, the levels of the impurities in Yendi (0.09%) and Nanumba-North (NN) (0.03%) were very low enough, thus, placed the shea butter in the two districts under grade 1. The extracted butter from Tolon district with insoluble impurities of 0.14% is put under grade 2 while that of the shea butter extracted from Savelugu-Nantong which was contaminated with impurities of 0.27% is placed under grade 3.

With reference to the quality parameters obtained from each of the shea butter extracted in the four districts, the butter in the Nanumba-North district was the highest quality shea butter, belonging to grade 1 in term of peroxide value, grade 1 in terms of free fatty acids and grade 3 in terms of insoluble impurities. The next quality shea butter is the Yendi shea butter which is characterized as grade 1 per the value of peroxide, grade 1 in terms of insoluble impurities and for the level of free fatty acids the butter is classified as grade 3. The shea butter from Tolon is ranked third as its peroxide value, free fatty acids and insoluble impurities put the butter under grades 1, 3 and 2 respectively. The lowest quality shea butter was extracted from Savelugu-Nanton district, where its peroxide value has placed the butter under grade 1. The free fatty acids and the insoluble impurities put the butter in the district under grade 3, 3 respectively. However, all the shea butter were extracted by the traditional method thus require further drying since the moisture contents of butter fall out of the range prescribed by the Technical committee of West Africa Regional quality Standard for unrefined shea butter (2006).

The mean value of free fatty acids of 5.37% classifies all the shea butter across the districts in the Northern region under Group 3. The mean peroxide value of 8.06% as shown in **Table 4.3** puts the shea butter from these districts under Group 1. This means that shea butter from Tolon, Yendi, Savelugu-Nantong and the Nanumba North districts are classified as those suitable to be used in cosmetic and pharmaceutical industries and for direct consumption including uses in making soap and can further be refined for direct consumption

4.4 Relationship between soil Physical and Chemical Properties and shea butter quality

The recovery of shea butter from the nut was based on the traditional extraction concept. Several factors affect both the physical and chemical properties of the shea butter, including soil, the one factor that influences the growth and fruits of almost all plants including the shea tree. As displayed in Figure 4.3, it is clear that the amount of butter in the nut of the shea fruit is influenced by the organic matter content, the organic carbon content, the organic nitrogen content of the soil where the shea tree is located. It is also greatly influenced by CEC. The volume of the shea butter also depends on the moisture content of the extracted butter.

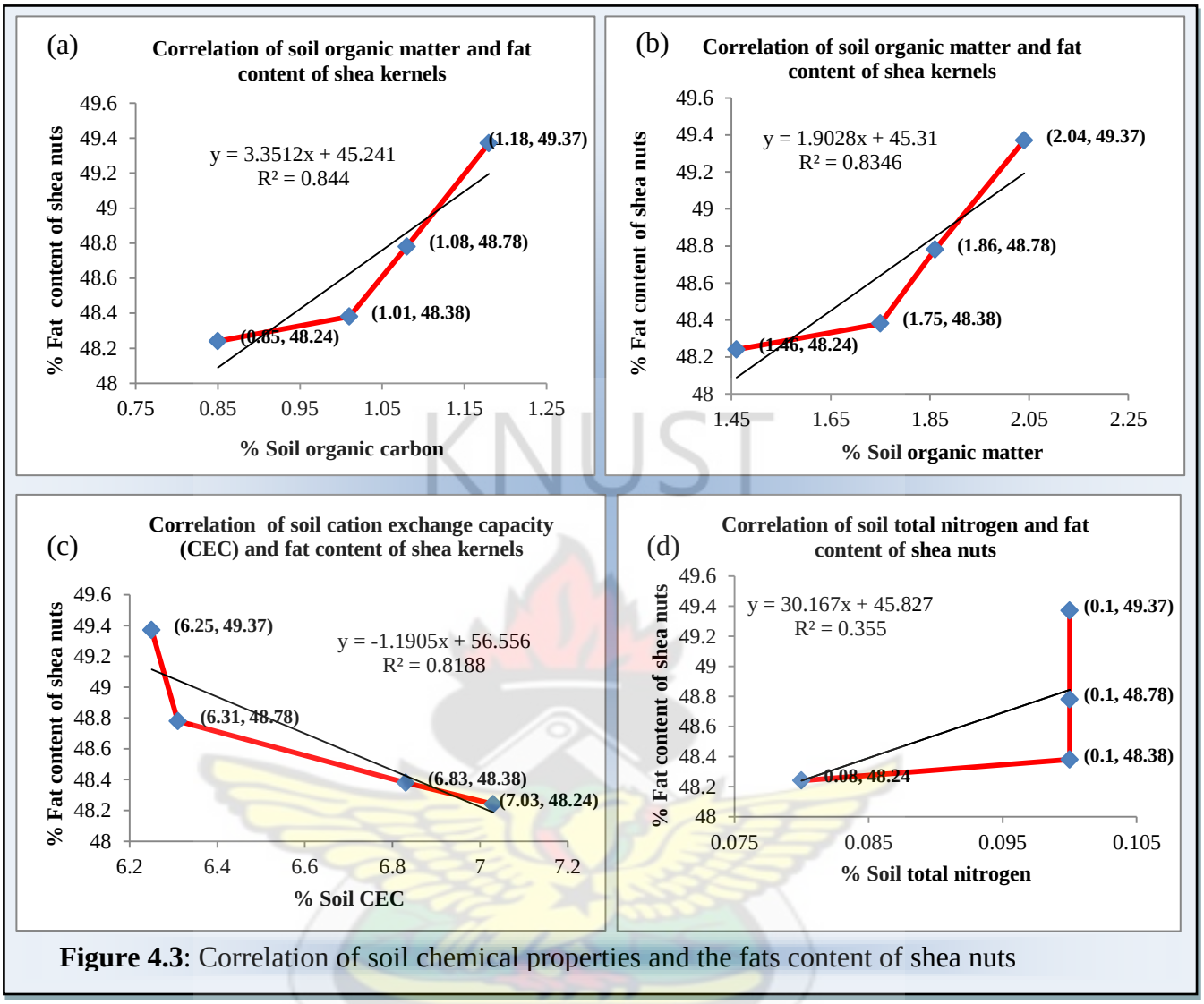


Figure 4.3: Correlation of soil chemical properties and the fats content of shea nuts

The colour of shea butter extracted from shea kernels in Northern Region of Ghana by visual examination is usual whitish-yellow. However, this colour can be manipulated to golden through the addition of roots of some plants such as *Cochlospermum planchonii* (Agyente and Kwame, 2010). The colour intensities of shea butter extracted from the four districts in the Northern regions of Ghana in this study are presented in **table 4.1.** The dominant colour of the shea butter from the findings was yellow. It ranges from 33% to 70% with 55.5% occurring as the mean value. The other detected colour was the red colour intensity which has a mean

percentage of 3.01, and ranged from a minimum value of 2.15 to a maximum value of 4.00%.

Displayed in the table of the values of the coefficient of determinants (R^2) in appendix (**I**), it is clear that the soil characteristics across the four shea producing district did not show any define relationship with the colour of the shea butter. Thus, soil chemical and physical properties have no influence on the colour of shea butter. This supports Omujal (2009) assertion that the colour of oil is genetic, it comes from the natural colouring matters such as α- carotene, β-carotene and xanthophylls which already are inherent traits in plants.

The mean moisture content of the shea butter by the findings of this research was 5.37%. The minimum moisture content (4.70%) was recorded at Nanumba North district and the maximum moisture content was found in shea butter from the Yendi Municipality as shown in the R^2 values in appendix (I) and the correlation graphs in appendix (II) , the soil properties by all estimation have not shown any influence on the moisture content of shea butter. One would have thought that the soil with the highest water holding capacity (9.31% at Tolon) due to turbidity would have an influence on the moisture content. On the contrary, shea butter moisture content and percentage clayey soil have no direct relationship (see Table 4.2 and Appendix III respectively).

Meanwhile moisture is a chemical contaminant which is usually well mixed with oil and significant amount of moisture in oil support microbial growth (Alirezali et al., 2011) and lipid oxidation leading to rancidity (Hee, 2011) and thereby reducing the shelf life of the shea butter. The moisture content influences the volume of the fat content. Low moisture content indicates good quality butter (Olaniyan and Oje,

2007). The minimum moisture content (4.70%) of the butter in this study compared to the minimum 5.23% (Quaioo et al, 2013) is lower. Per the African Regional Standards (0 – 2.0)% (RTC, 2006) the shea butter from the four districts under this study needs further drying possess to make them suitable to be used in the cosmetic, pharmaceutical, food and soap making industries.

Insoluble impurities generally do not have much link with soil properties. (See appendix I and II). They normally get into the shea butter through processing and handling of the shea butter from the production centre to the end user. The findings of this research indicate that the shea butter from the Savelugu-Nantong district is the most contaminated with Nanumba North being the least contaminated. Hamilton *et al* (1986) and Hee (2011) agree that insoluble impurities in shea butter refer to dirt and other foreign materials.

In the case of shea butter yield, the highest amount of butter (49.37%) was found in shea nuts from the Yendi Municipality and the least (48.24%) of shea butter yield from the Tolon district. The volume of butter yield at the Yendi Municipality could have been influenced by the amount of moisture remaining in the butter since shea butter from the Yendi Municipality has the highest moisture content (6.65%). The mean butter yield according to this research was 48.69%. Across all the districts, the soil organic carbon content, the soil organic matter content and the soil nitrogen content as illustrated in figure 4.3 were directly proportional to the shea butter yield. The shea butter yield (49.37%), soil carbon (1.18%), organic matter (2.04%) and soil nitrogen (0.10%) were all highest at Yendi Municipality and least (48.24, 0.85, 1.46 and 0.08% respectively) at the Tolon district. The implication of this observation is that soils within the Yendi Municipality are richer in plant nutrients, especially

nitrogen and organic matter, than the other districts and therefore shea fruits from the Yendi Municipality have more butter content than shea fruits from the other district considered in this study.

Nitrogen is combined in stable organic matter that decompose very slowly and about 2,000 to 6,000 lb/a of organic nitrogen are found in soils (Bundy, 1998). This explains why the Yendi Municipality which has the highest organic matter content also contains the highest amount of nitrogen together with Savelugu and Nanumba North Districts (Table 4). The nitrogen content of soils across the four districts in the current study was generally low (<0.12%). Tucker (1999), reports that nitrogen promotes rapid growth, increases leaf size and quality, hastens crop maturity, and promotes fruit and seed development. Because nitrogen is a constituent of amino acids, which are required to synthesize proteins and other related compounds, it plays a role in almost all plant metabolic processes. Nitrogen is an integral part of chlorophyll manufacture through photosynthesis. Photosynthesis is the process through which plants utilize light energy to convert atmospheric carbon dioxide into carbohydrates. Carbohydrates or sugars provide energy required for growth and development (Tucker, 1999). The chemical equation for photosynthesis is

$$6CO_2 + 12H_2O + 672\ Kcal\ radiant\ energy \rightarrow C_6H_{12}O_6 + 6H_2O + 6O_2$$

Formation of fats in seeds and fruits occurs late in the ripening process. Sugars and starches predominate in fruits, seeds, and sap in the unripe condition. These apparently are converted by enzymes during the maturing process to fatty acids and glycerol, which then form glycerides (Tucker, 1999). What this means is that the unripe shea fruits will have no or little fat and this explains why woman will pick only the fallen nuts which are naturally matured.

The amount of shea butter in the shea nut kernel across the districts is influenced also by the Cation Exchange Capacity (CEC). As can be seen in figure 4.3, the CEC show a strong negative correlation with the yield of the shea butter across the four districts. The least amount of butter (48.24%) was retrieved at Tolon which has the highest CEC of 7.03%. The Yendi Municipality recorded the highest butter (49.37%) content and the least CEC of 6.25%. The CEC measures the extent to which soil can hold and exchange plant nutrient cations. The ability of soil to hold positively charged nutrients from being leached and lost from soil is important to maintaining soil fertility. Clay and organic matter have a negative charge. They allow the soil to hold these nutrient cations due to the attraction of charges. Soils with high clay or organic matter content will have a higher CEC. Sandy soils tend to have a lower CEC. Tolon had the highest clayey soil and the least sandy soil contents as shown in **Figure 4.1**. As a result the lowest organic carbon, organic matter and soil nitrogen are recorded in Tolon and hence the lowest butter content.

Phosphorus and potassium were highest (4.31% and 0.24% respectively) at Savelugu and least (2.49% and 0.16% respectively) at Tolon and Yendi respectively. The ready availability of potassium, phosphorus and nitrogen is not inconclusive. It is directly linked with the soil pH of 5.74 (Appendix III) at Savelugu. At pH range of 5.5 to 7.5, there are sufficient microorganisms to breakdown the organic matter (Cooper, 1997); it is the best range for nutrient availability for plant uptake and so the second best yield of shea butter was at Savelugu. Phosphorus is a constituent of nucleic acids, phospholipids, the coenzymes DNA and NADP, and most importantly ATP. It is involved in metabolic processes required for normal growth such as glycolysis and fatty acid synthesis and aids in seed formation. The phosphorus content in soils of

northern Ghana is between 2.49% to 4.31% as shown in the composite table 4.4 below

Table 4.4: Shea butter fats compared to soil chemical properties

District	%Butter Fats	%Soil OC	%Soil OM	%Total soil Nitrogen	%Soil CEC	%Soil Phosphorus	% Soil Exchange potassium
Tolon	48.24	0.85	1.46	0.08	7.03	2.49	0.23
Yendi	49.37	1.18	2.04	0.10	6.25	2.89	0.16
S-N	48.78	1.08	1.86	0.10	6.31	4.31	0.24
NN	48.38	1.01	1.75	0.10	6.83	2.94	0.17
p-value	0.001	0.001	0.001	0.001	0.002	0.001	0.001

The specific gravity, which depicts the relative density of shea butter, according to this research is 0.91 across the shea producing centre. Many researchers (Hee, 2011; Munir *et al*, 2012; RTC, 2006) have reported this value for shea butter. Irrespective of the changing soil physical and chemical properties, the specific gravity remains the same. And thus soil chemical and physical properties have no effect on the specific gravity of shea butter. The density of a substance has a direct relationship with the chemical composition (Molecular mass) of that substance (see table 4.3).

The chemical properties of the shea butter (free fatty acids, acid value, pH, peroxide value, iodine value, ester value, Saponification value and Unsaponifiable value) do not have any predictable relationship with the soil properties (see appendix I). This observation suggests that irrespective of the varying soil properties the chemical composition of shea butter will remain the same. The findings of the current research

compares well with that of Adomako, 1997; Asuquo et al 2006 and Agyente, 2010 as shown in the table (Table 4.5) below.

Table 4.5: Comparison of Chemical Properties of Shea Butter

	Various Sources			
Shea butter properties	Adomako,1997 and Agyente, 2010	Asuquo, et al, 2006)	Hee,2011	Current study
Colour		milky cream	whitish yellow	Whitish yellow
Refractive index		1.60	1.50	1.47
Specific gravity		0.92	0.91	0.19
Peroxide value		14.20	12.03	8.06
Moisture content		10%	13%	5.37%
Saponification value	184.80	185.20		185.00
Iodine value	64.20	63.45		59.44
Ester value		183.40		174.10
Acid Value	13.40	1.79		10.76
Usaponifiable value	8.15	5.68	2.45	4.12
Free fatty acid	6.80		5.01	5.30
Insoluble impurities			0.14	0.13

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The most interesting findings of this research are that the shea nut trees are common in soils with high percentage of sand and very low percentage of clay. They are also common in areas where the soil cation exchange capacity is low. The results indicate that where there were high levels of sandy soils, there were equally low cation exchange capacity and this had shown some relation with the fat content. Thus, CEC was inversely proportional to the shea butter extracted.

Another finding that was made in the research was that, the organic matter and the organic carbon contents of soil were positively correlated with quantity of shea butter in the shea kernels. These parameters of the soil were directly proportional to the percentage shea butter extracted from the shea kernels.

The present research has also revealed that, that soil properties have no predictable relationship with the shea butter chemical properties which has a huge responsibility in determining the quality of shea butter. The shea butter, according to this research, fall within the various grading systems of shea butter established by the Regional Technical Committee of African Regional Standards for unrefined shea butter, and thus can be used in the pharmaceutical, confectionery, food and the cosmetic industries.

5.2 RECOMMENDATION

1. Parameters such as the fatty acid profile, tocopherol level, as well as the glycerol content which are all characteristics that measure shea butter quality were not captured in this research. The correlations between the soil and shea butter were based only on few dataset with the parameters of the shea butter. This is a relatively not much enough and with the inclusive of the above mention parameters would have enabled correlations to be more founded and put forth with greater confidence. Further research should therefore expand to include a more detailed analysis of the butter. In particular, information on the above mentioned parameters.

2. The traditional method of shea butter extraction was adopted for this research work. Although, the method appeared to be familiar and widely used by the small scale shea butter extraction industries especially in the Northern Region of Ghana, it suffers in term of accurate measurement of extraction condition at various points of extraction processes. This may cause deviation of the shea butter physicochemical properties from normal. It would therefore be significant and prudent if other methods such as solvent extraction method as well as mechanical extraction methods could be used to investigate the effect.

3. Also, as shea butter is product of shea nut obtain from shea tree which derived it nutrients from the soil, a research need to be conducted on the effect of soil nutrient variation on the quality of the nutritional value of fruits and the shea kennel.

4. The effect of post-harvest activity of shea nuts and the type of methods adopted for butter extraction on the physico-chemical properties of shea butter can also be investigated.

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APPENDICES

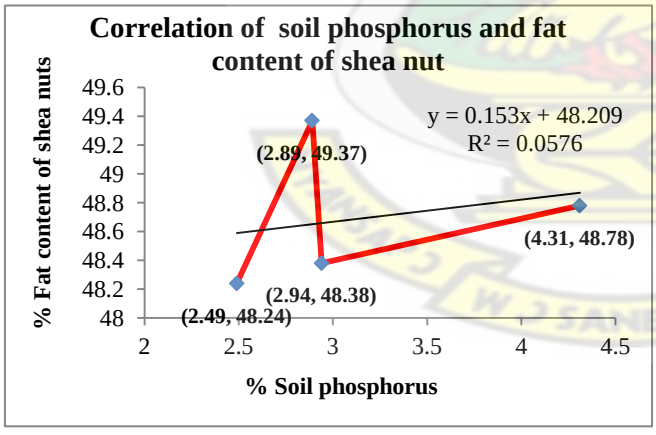
Appendix I

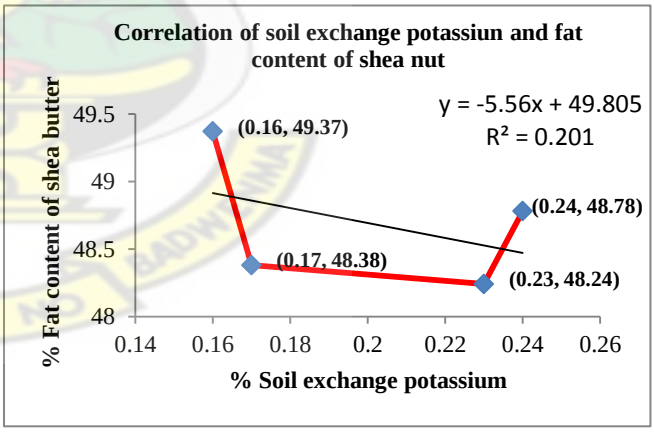
Coefficient of determinant (R^2) between soil chemical properties and shea butter physical and chemical properties

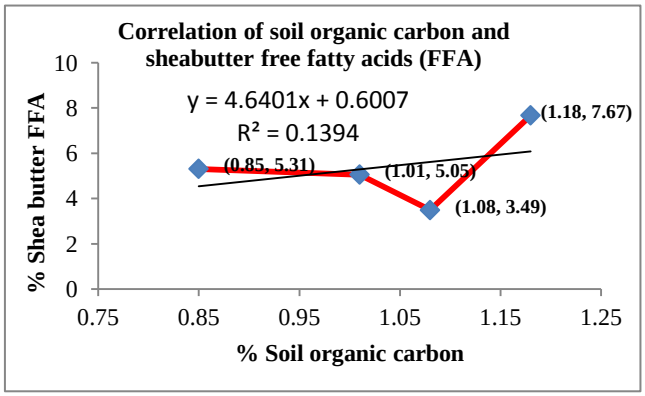
Parameter	%OC	%OM	%CEC	% Total Nitrogen	% Phosphorus	Exchange Potassium
	R^2	R^2	R^2	R^2	R^2	R^2
FFA	0.14	0.14	0.03	0.00	0.42	0.57
AV	0.14	0.14	0.03	0.00	0.42	0.57
Butter pH	0.44	0.42	0.74	0.08	0.23	0.02
PV	0.01	0.01	0.03	0.27	0.63	0.10
IV	0.02	0.02	0.00	0.05	0.60	0.38
EV	0.27	0.27	0.16	0.01	0.21	0.42
SV	0.39	0.39	0.39	0.03	0.03	0.18
UV	0.01	0.01	0.08	0.16	0.05	0.02
Fat content	0.84	0.83	0.82	0.35	0.06	0.20
IM	0.00	-0.00	0.15	0.00	0.21	0.30
YC of butter	0.00	0.00	0.05	0.04	0.80	0.56
MC of butter	0.25	0.25	0.20	0.00	0.14	0.25

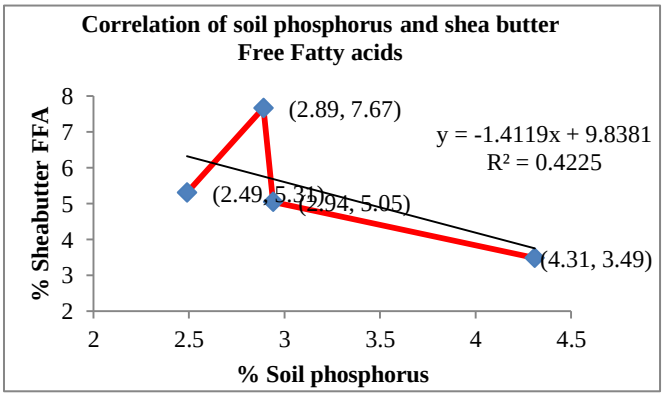
Appendix II:

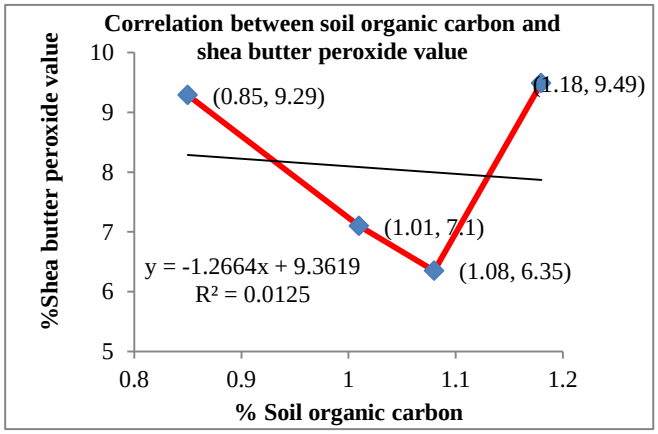
Graphs of Correlation of Soil Properties to the Shea Butter Properties

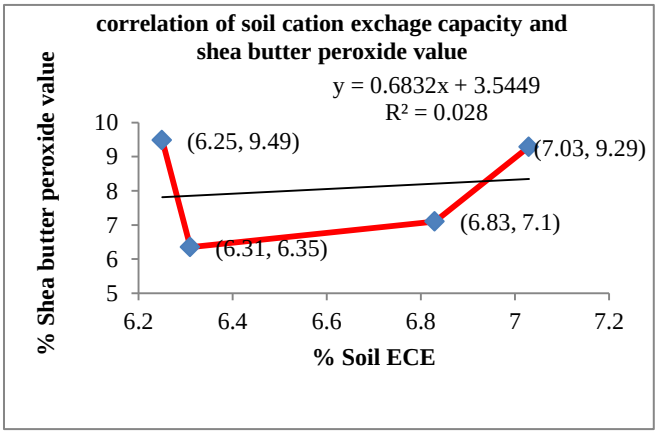


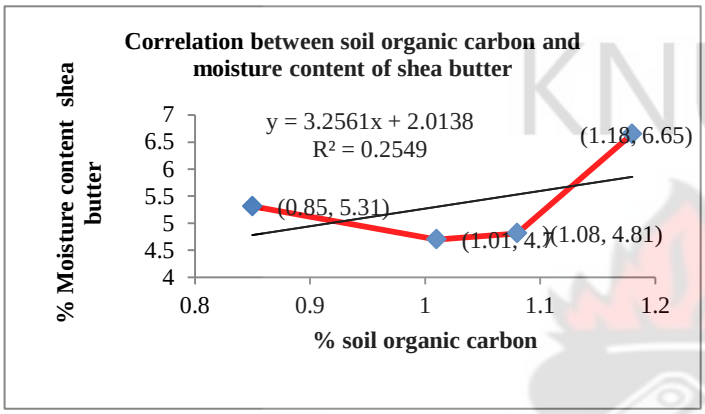


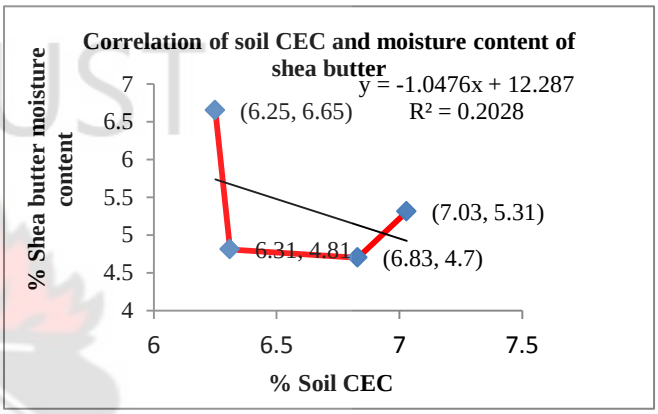


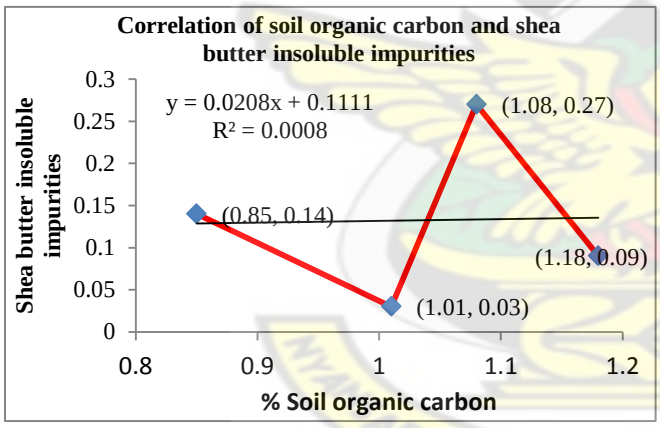


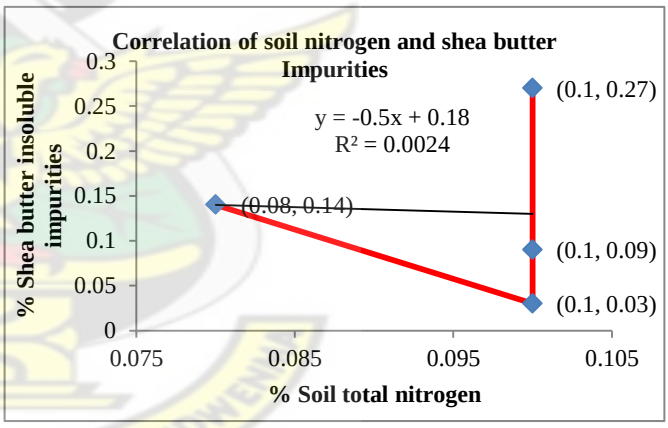

Correlation between soil organic carbon and shea butter peroxide value
%Shea butter peroxide value
% Soil organic carbon
(0.85, 9.29)
(1.01, 7.1)
(1.08, 6.35)
(1.18, 9.49)
y = -1.2664x + 9.3619
R² = 0.0125


correlation of soil cation exchage capacity and shea butter peroxide value
% Shea butter peroxide value
% Soil ECE
y = 0.6832x + 3.5449
R² = 0.028
(6.25, 9.49)
(6.31, 6.35)
(6.83, 7.1)
(7.03, 9.29)


Correlation between soil organic carbon and moisture content of shea butter
% Moisture content shea butter
% soil organic carbon
y = 3.2561x + 2.0138
R² = 0.2549
(0.85, 5.31)
(1.01, 4.7)
(1.08, 4.81)
(1.18, 6.65)


Correlation of soil CEC and moisture content of shea butter
% Shea butter moisture content
% Soil CEC
y = -1.0476x + 12.287
R² = 0.2028
(6.25, 6.65)
6.31, 4.81
(6.83, 4.7)
(7.03, 5.31)


Correlation of soil organic carbon and shea butter insoluble impurities
Shea butter insoluble impurities
% Soil organic carbon
y = 0.0208x + 0.1111
R² = 0.0008
(0.85, 0.14)
(1.01, 0.03)
(1.08, 0.27)
(1.18, 0.09)


Correlation of soil nitrogen and shea butter Impurities
% Shea butter insoluble impurities
% Soil total nitrogen
y = -0.5x + 0.18
R² = 0.0024
(0.08, 0.14)
(0.1, 0.27)
(0.1, 0.09)
(0.1, 0.03)

Appendix III.

Percentage Soil Physical Composition in Shea Growing Areas

District	%Sandy	% Silt	% Clayey	Soil PH
Tolon	52.04	38.65	9.31	5.22[c]
Yendi	62.04	32.65	5.31	5.33[a]
Savelugu	66.60	28.67	4.73	5.74[b]
N'ba North	66.39	26.69	6.92	5.28[a]
P-Value	0.001	0.001	0.001	0.001

Appendix IV

Chemicals Used

- 0.1N Hydrochloric Acid
- 1.0 M Ammonium Acetate
- 30% Hydrogen peroxide
- 40% Boric Acid
- 40% Sodium Hydroxide
- 5% sodium hexametaphosphate
- Acetone
- Amyl alcohol
- Conc. Tetraoxosulphate (VI) Acid
- Diphenylamine indicator
- Distilled water
- Ferrous sulphate solution
- Hexane
- Molybdate reagent
- Orthorphosphoric acid
- Potassium dichromate
- Sodium acetate

Appendix V

Materials

- Sand samples
- Shea butter samples

Appendix VI

Apparatus

- 100ml beaker
- 2mm sieve
- Asbestos sheets
- Bouyoucos Hydrometer
- Erlenmeyer flask
- Kjedahl flask
- Mechanical shaker
- Pipette
- Sedimentation cylinder
- Spatula
- Volumetric flask
- Whatman Filter paper

Instruments

- Plane photometer
- HI electrode meter
- Centrifuge
- Spectrophotometer
- Soxtherm Analyser
- Tintometer
- Oven
- Refractometer