POST HARVEST HANDLING PRACTICES AND PHYSICO- CHEMICAL CHARACTERISTICS OF SHEA (*Vitellaria paradoxa*) FRUIT IN UGANDA

BY

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DECLARATION

I declare that this research work has been done by me and has never been submitted to any University or Insitution of higher learning for any award. All sources consulted have been referenced.

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DEDICATION

I would like to dedicate this work to my family and the shea parkland communities of Uganda.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS /ACRONYMS

AACC	- American Association of Cereal Chemists
ANOVA	- Analysis of Variance
AOAC	- Association of Official Analytical Chemists
Ca	- Calcium
CBE	- Cocoa Butter Equivalent
CBI	- Cocoa Butter Improver
CFC	- Common Fund for Commodities
COVOL	- Cooperative Office for Voluntary Organization
cP	- Centi Poises
CRIG	- Cocoa Research Institute Ghana
DCPIP	- Dichloroindophenol
DM	- Dry matter
FAME	- Fatty Acid Methyl Esters
FAO	- United Nations Food and Agricultural Organisation
Fe	- Iron
FID	- Flame Ionization Detector
FP	- Fresh Pulp
GC	- Gas Chromatography
Gr	- Green
HCL	- Hydrochloric acid
HPLC	- High Performance Liquid Chromatography
K	- Potassium
KA	- Katakwi and Arua
Kg	- Kilograme
KOH	- Potassium Hydroxide
KP	- Katakwi and Pader
LA	- Lira and Arua
LK	- Lira and Katakwi
LP	- Lira and Pader
MAAIF	- Ministry of Agriculture Animal Industries and Fisheries

Mg	- Magnesium
Mg	- milligrams
MT	- Metric tonnes
na	- Not Applicable
Na	- Sodium
NRC	- National Research Council
NUSPA	- Northern Uganda Shea Processors Association
Or	- Orange
PA	- Pader and Arua
pmm	- Parts per million
PROTA	- Plant Resources of Tropical Africa
PV	- Peroxide value
RPM	- Revolutions per Minute
SMC	- Spindle Multiplier Constant
SPSS	- Statistical Package for Social Scientists
UN	-United Nations
UNBS	- Uganda National Bureau of Standards
USA	- United States of America
USAID	- United States Agency for International Development
UV	- Ultra Violet
V/W	- Volume/Weight
Yel	- Yellow

ABSTRACT

This study assessed the post harvest handling practices and physico chemical characteristics of shea butter in the parkland areas of Uganda. To investigate post harvest practices of shea butter (*Vitellaria paradoxa)* fruit, a total of 275 respondents were interviewed between July 2007 and January 2008. The collected socio-economic data were coded, entered in SPSS computer programme and analysed. In the same period, fresh shea fruit pulps were collected, dried and analyzed for proximate and mineral compositions. The shea butter oil extracted from the shea kernels of the shea fruit were also analysed for variability in physico chemical characteristics and fatty acid profile extracted by n-hexane solvent, traditional boiling and mechanical cold pressing methods. The proximate analysis showed that the shea fruit pulp, crude oil, crude fibre, crude protein, total carbohydrate, vitamin C and caloric value contents ranged between 1.5-3.5%, 10-15%; 3.1-4.2%, 61-64%, 85.59-124.86mg/100g and 248-256 Kcal/100g, respectively. The mineral composition of the shea fruit pulp consisted of calcium 35.18-95.58 mg/100g, potassium 42.04-63.55 mg/100g, magnesium 18.14-24.21mg/100g, sodium 7.07-18.12 mg/100gm and iron 3.41-3.76 mg/100g. The shea seed kernel butter/oil content ranged between 41-54% and the physico chemical characteristics such as colour, refractive index, viscosity, acid value, peroxide value, saponification value, iodine value and α- tocopherols ranged between orange to orange–yellow, 1.670-1.690, 2.4-2.8cP, 2.3-12.59mgKOH/kg, 2.10-2.50meq/kg, 160- 192mgKOH/g, 39.21-41.37 I_2g/100g and 26.3-44.4mg/100g, respectively. The shea butter fatty acid profile: palmitic , stearic, oleic, linoleic and arachidic acid fatty acids ranged between 6.52-8.12%, 28.65-30.94%, 55.54-57.63%, 6.18-7.79% and 0.65-0.90%, respectively. The physico-chemical characteristics of shea butter extracted by n-hexane solvent extraction, traditional boiling and cold pressing methods for the colours, refractive index, viscosity, acid value, peroxide value, saponification value, iodine value and α tocopherols ranged between yellow-orange to yellow-red; 1.468-1.469, 2.4-2.8cP, 2.3-6.9mgKOH/kg, 2.2-5.09mEq/kg, 145-192mgKOH/kg, 36-38 I_2/100, 34.4-45.5mg/100g while the fatty acid profile: palmitic , stearic, oleic, linoleic and arachinic acid fatty acids ranged between 6-8%, 29-31%, 55-57%%, 6-8%and0.65-0.98%, respectively. While the proximate and mineral composition of the shea fruit pulp makes shea fruits a potential nutritious fruit in the parklands, the physico-chemical characteristics and fatty acid profile of shea butter on the other hand make it a suitable raw material for food, cosmetic and pharmaceutical products. The quality of shea butter oil is also comparable to other edible oils such as soya bean oil (*Glycine max*). The indigenous post harvest handling practices of shea butter in Uganda is appropriate, however, there is a need to investigate further their influence on quality of shea butter..

CHAPTER ONE

INTRODUCTION

1.1 Background

In Sub-Saharan Africa, many indigenous fruit trees although undomesticated play an important role in sustaining the livelihoods of people living in rural areas (Maghembe *et al*., 1994). These trees are important traditional sources of fruits, beverages, nuts and edible oil (Okafor, 1985). The nutritional value of indigenous fruit bearing tree species indicates that many are rich in sugars, essential vitamins and minerals while some of their seeds are high in edible oil and proteins. The seeds have the potential of serving as the main source of edible vegetable oil for many rural people and in the economy of many countries (Ullah *et al.,* 2003).

The shea tree (*Vitellaria paradoxa*) is one of such indigenous wild fruit trees with enormous nutritional benefits. This fruit tree is found in the parkland belts stretching from Senegal through Sudanian region, to Western part of Ethiopia (White, 1983). The eastern sub species *nilotica* occurs in Ethiopia, southern Sudan and north-eastern Uganda (Katende *et al*., 1995). The fruit pulp and oil from the shea nuts have been reported to be vital for supporting the livelihoods of the parklands communities (Hall *et al*. 1996; Okullo *et al*. 2004; Maranz *et al.*, 2004). The fruit is edible with a nutritious sweet and spice able flavour pulp. The fruit pulp is also a source of food for other animals such as elephants, sheep, pigs, bats and birds (USAID, 2004). Apart from the fruit playing an important role in the diets it is also sold in local markets (FAO, 2007). In Uganda the shea tree is a dominant indigenous tree species in the savannah wood lands of north, north eastern and West Nile sub regions of Uganda (Okullo *et al.,* 2004). Due to its multiple uses, the tree has been described as a 'Green Gift from God's to man Kind' (Guru, 2007).

The fruits and nuts or seeds obtained from the shea tree are of nutritional and economic significance to the communities around the parklands (Prokarite, 2007). According to Leakey, (1999) Maranz *et al.,* (2004), shea oil extracted from the seed kernels is the main source of fat for preparation of sauce, frying and baking in addition to being a cosmetic and traditional medicine in many rural areas. In fact the seed kernels produce high oil content which is nutritious with unsaturated fatty acids such as oleic and linoleic fatty acids and fat soluble vitamins (Karin, 2004; Kapseu, *et al.,* 2007).

Although shea butter is important in food, cosmetic and pharmaceutical industry, variations between physico-chemical compositions and fatty acid profile have been reported in different countries (Maranz *et al.,* 2004; Dei *et al;* 2007). Such variations in physico-chemical compositions have been attributed to environmental factors such as climate, temperature, soil fertility; maturation period; agronomic practices and genetic substitution. Besides, it has also been suggested that post harvest handling practices such as fruit harvesting, seed drying, storage and oil extraction processes may cause variation in physico-chemical characteristics of shea butter (USAID, 2004). It was with these views in mind that this study assessed the post harvest handling practices and chemical and nutritional composition of shea butter (*V. paradoxa*) in Uganda.

1.2 Statement of the Problem

Shea fruits, nuts and oil are of great nutritional and economic significance to many African countries. For example, Africans in the shea growing districts depend on shea butter as their substitute for the valuable dairy butter, a natural source of vitamins and a source of income (Bayala, 2004). Since shea fruits, nuts and shea butter oil remain a primary source of essential food nutrients, not much research has been carried out on influence of post harvest handling in the nutritional and chemical composition of the shea fruit pulp and shea butter..

Although variability in proximate , physico-chemical and fatty acid profile due to geographical and environmental conditions have been reported by Maranz & Wiesman (2003), variability in physico chemical characteristics as a result of post harvest handling practices has not been investigated. According to USAID (2004), post harvest handling practices including fruit harvesting, seed drying, storage and oil extraction processes are critical in determining the quality of shea butter.

There has therefore been a need to assess post harvest handling practices, nutritional and chemical compositions of fruit pulp, shea butter and associated products as this would provide information that can be used by the local community, development partners, researchers and individual farmers to design appropriate programmes for improving income and food security among rural communities, especially in the shea parkland zones of Uganda.

In order to involve rural communities in sustainable use of shea butter trees and related products, there is also need to generate knowledge on nutritional values,

post harvest practices and pyhsico-chemical characteristics of shea fruit pulp and oil respectively. Following the above, this study assessed the proximate and mineral composition, post harvest handling practices and physico chemical characteristics of shea oil among the ethnic communities within the shea parkland zones of Uganda.

1.3 Objectives

1.3.1 General Objective

The general objective of the study was to assess the nutritional and chemical composition of shea fruit pulp and shea butter in relation to post harvest handing practices in the shea range districts of Uganda.

1.3.2 Specific Objectives

The specific objectives of the study were:

1. To document the ethno-nomenclature and post harvest indigenous knowledge/practices of shea fruit products in the shea range districts of Uganda.
2. To determine the proximate and mineral composition of shea fruit pulp in the shea range districts of Uganda.
3. To examine the physico-chemical characteristics and fatty acid profile of shea oil in the shea range districts of Uganda.
4. To establish variation in physico-chemical characteristics of shea butter oil extracted by different processing methods in the shea range districts of Uganda.

1.4 Hypotheses

The hypotheses for this study were:

i. There is no wide variation in the chemical and nutritional composition of the shea fruit pulp and shea butter in the shea range districts of Uganda.
ii. There is no variation in physico-chemical characteristics of shea butter extracted by different processing methods in the shea range districts of Uganda.

1.5 Justification/Significance

The products from the shea tree are vital for supporting the livelihoods of parklands rural communities (Hall *et al*. 1996; Okullo *et al*. 2004). For example, while the shea fruit pulp is edible, the shea butter has been used for centuries as food, medicine, and cosmetic and soap making among shea producing communities in Africa and also for

export to Europe (Boffa, 1999). Because of these values and affordability of shea butter as vegetable fat in shea producing areas and beyond, a study focusing on establishing and generating data on nutritional and chemical composition of the fruit pulp and shea butter oil in Uganda was timely. Since in Uganda there are no approved standard for shea butter and shea related product, this study has provided a baseline database or information for the development of shea butter standards.

Furthermore, the findings have become a benchmark for further research on quality, commercialization and value addition of various shea butter products including development of proper post harvest handling practices that have been lacking in Uganda. From the development perspective, assembled information would be used by the community, development partners, researchers and individual farmers for improving income and food security among rural communities especially in the shea butter parkland areas of Uganda. Apart from the above, the information obtained can also be used to improve marketing and utilization of shea butter and shea related products in the region.

1.6 Theoretical Framework

This study was designed based on the theoretical framework which would assess the nutritional and chemical composition of shea fruit pulp and shea butter in the shea zones of Uganda (Figure 1).

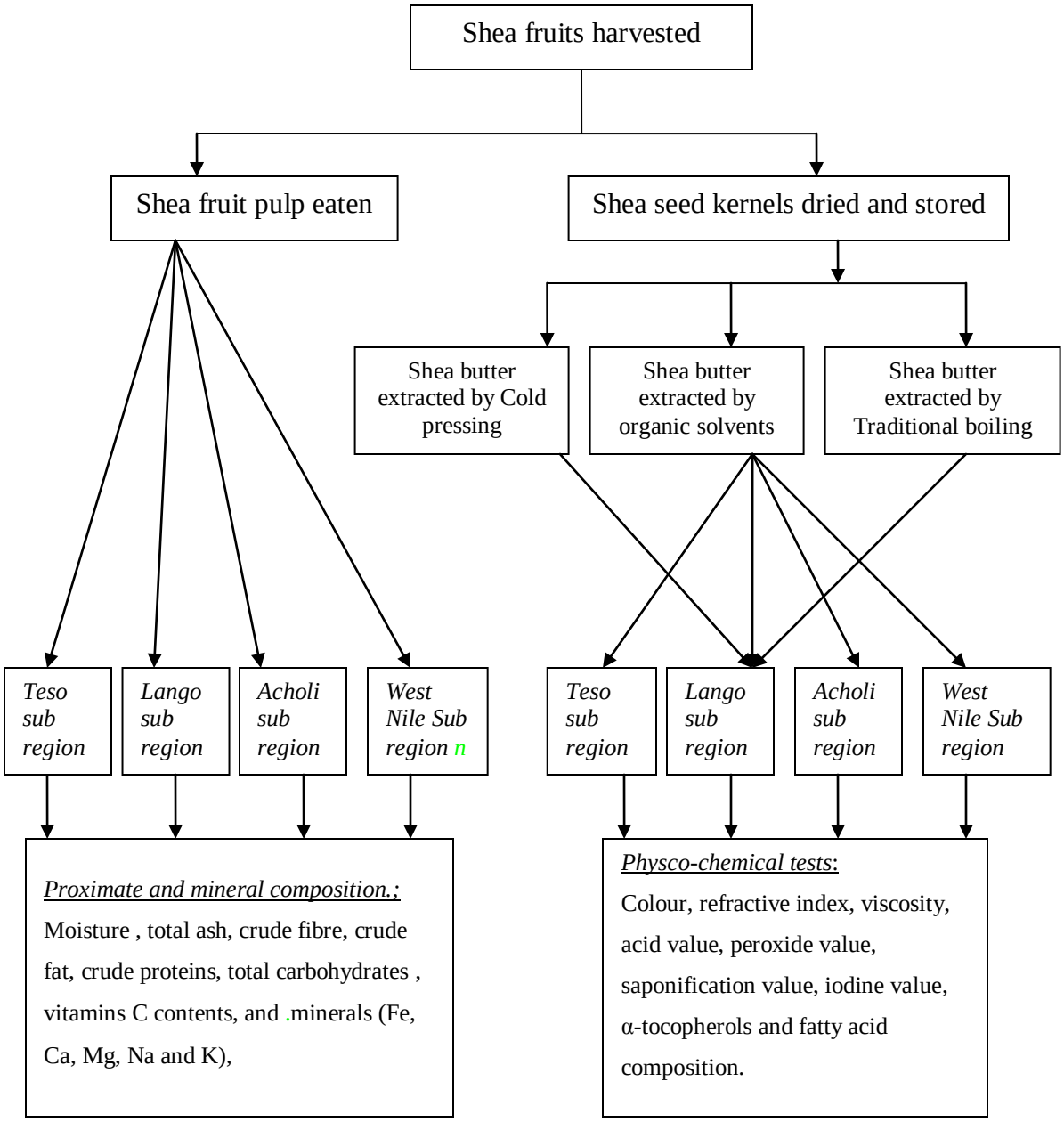


Figure 1: Theoretical frame work for the study

1.7 Scope and Structure of the Dissertation

This study assessed the ethno nomenclature and post harvest practices of shea butter in shea zones of Uganda. The study also involved the shea fruit nutrients and physico chemical characteristic of shea butter in different shea districts of Uganda. Variation in physico chemical characteristics of shea butter extracted by different methods was also investigated.

This dissertation is structured into six chapters as follows. Chapters 1 to 3 are for introduction, literature review and materials and methods for the whole study. Chapters 4, 5 and 6 are for Results ,Discussion and Conclusion and recommendations. This is then followed by References and Appendices respectively.

CHAPTER TWO

LITERATURE REVIEW

2.1 General issues on *Vitellaria paradoxa*

2.1.1 V. paradoxa plant species

Vitellaria paradoxa also called the shea tree belongs to sapotaceae family and is one of the most dominant and abundant species found in semi arid areas of at least 19 Sub Saharan African countries (Hall *et al.*, 1996). This tree grows to a height that ranges from 8 to 23 metres and has many spreading branches in the areas with temperatures range of 24 – 32^{o}C and rainfall between 800 - 1400 mm per annum (FAO, 2001). There are two sub species of the shea tree. The sub species *Vitellaria paradoxa* is the one growing in West Africa and sub species *Vitellaria nilotica* southern Sudan, Ethiopia and Uganda (Hall *et al.*, 1996). In Uganda, *Vitellaria sub species nilotica* is abundant in the northern parklands covering the areas of West Nile, Acholi, Abim (Acholi jabwor), Lango and Teso (Okullo *et al*., 2004).

2.1.2 Vitellaria paradoxa shea tree products

The shea tree does not only provides shea fruits , kernels and butter but it is also a source of fuel (charcoal), shade, medicine, traditional apiculture for placing hives and traditional cultural ceremonies (Maranz *et al* 2004). Other parts of the tree such as sap, leaves and roots have industrial potential application (USAID, 2007). Although this tree is very difficult to domesticate, it's being threatened by the charcoal industry in Uganda (Master and Puga, 1994, Okullo *et al.*, 2004).

a) Shea fruits: Fruiting of the tree commences only after 15-20 years (Karin, 2004) and reaches full maturity after 45 years (FAO, 2001). The trees fruit at the end of the dry season and are harvested during rainy season between the months of May and August (Okullo *et al.*, 2004). The fruit takes 4-6 months to develop and each tree produces 15-20kg of fruits (Karin, 2004). The ripening improves the taste to the sweet pear taste and the colour is greenish-yellowish with ellipsoidal shape (10–15 cm) or spherical berry with two to three grains per fruit. According to Maranz *et al.*, 2004, FAO, 2007 and Kapseu, *et al.*, 2007, the pulp of the fruit is edible with sweet and spice able flavour, play an important role in the local diet, can also be sold in the

local markets and can be used as a source of food for other animals such as elephants, sheep, pigs, bats and birds.

b) Shea nuts: Each fruit contains a kernel with oval or round hard red brown or dark brown seed referred to as a "shea nut". The fresh nut size and shape of particular trees are distinctive (Boffa *et al.,* 2004) and contains 41%water, 18%residue, 21% oil and 20% husk (USAID, 2004). The shiny, smooth and fragile shea nut shell is always processed into the "shea kernel" whereby each tree can yield 3-6 kg (Leakey, 1999; FAO, 2007). The shea kernels are the main source of shea butter, sold for income and used as medicine (USAID, 2004; FAO, 2007).

c) Shea oil: After shelling, the shea kernels are processed into shea oil or butter which is tallow like substances that solidifies at room temperature to form a yellow, cream or grey colour (Adikini, 2002). The shea oil is used as food sauce, cosmetic, soap making and traditional medicine and is also traded in the international markets as a valuable raw material in the cosmetic, chocolate and pharmaceutical industry (USAID, 2004). It has been reported by many authors including Tallantire & Goode (1975); FAO (1998); Puganosa & Amuah (1991) that shea oil comprises fatty acids and vitamins which are essential in the human diet . As a result, Africans have mostly depended on it as their substitute for the valuable dairy butter and natural source of vitamins.

2.2 Post harvest handling practices of shea butter

2.2.1 Shea fruit harvesting

Once fruits are ripe, they fall down by themselves beneath the mother tree and it is left to become over ripe (Karin, 2004). During harvesting, the shea fruits are mainly collected from the ground by village women and children who move long distances from home to pick and gather them under the trees.. The children and women eat the pulp and remove the seed kernel. The shea fruits can be collected from as near as the homestead and as far as 10km or so. The collected fruits can then be transported in lots of 20kg to the village where processing takes place (Karin, 2004). In addition to eating, the pulp can also be removed by scraping, boiling, sun drying, fermentation

and boiling (FAO, 2007). The removed pulp can be dried and also processed into shea cakes (Master and Puga, 1994).

2.2.2 Shea nut drying

The shea nuts are usually sun dried for 1-2 weeks and dehusked to obtain the shea kernel which is further sun dried for another 1-2 two weeks. Although the shea kernels can sometimes be baked to concentrate the oil in the kernel and lengthen the storage period, this has been discouraged because it is a limiting factor to quality of shea butter. Methods of solar drying on polythene sheeting have been developed in some African countries, but they have limited durability (FAO and CFC, 2005). According to USAID (2004), the shea kernels can be stored for several years without spoilage by maintaining its moisture content between 6% and 7%. This is so because the drying process inactivates enzymes responsible for the build-up of fatty acids in the seed kernel (USAID, 2004).

2.2.2 Shea kernel storage

Shea kernels are stored in sacks, woven baskets and plastic buckets that are stored either in house, granary or kitchen floors. Sometimes the kernels are hanged in houses or kitchens instead of floors. In West Africa Jute bags from cocoa industry are widely applicable. Over the past decades, polythene bags or sacks have come into wide use for storage of shea kernels. However, this has been reported to stimulate fungal growth important for quality because they do not allow air circulation (FAO & CFC, 2005). Moreover, because of the recalcitrant properties of shea nuts, it storage is very difficult (Karin, 2004).

2.2.3 Shea butter processing/extraction

A report by USAID (2004) indicates that technologies that have been used for extracting vegetable oil including shea butter are traditional boiling, mechanical pressing and solvent extraction. However, for centuries, shea butter has been processed by indigenous traditional boiling method which has been described as labour intensive (Masters and Puga, 1994). This has made the quality of indigenous traditionally extracted shea butter variable (FAO & CFC, 2005).

Due to this, improved methods such as mechanical pressing (both manual and hydraulic) are being adopted in many African countries. Even then conventional

motorized oil expellers are not recommended for shea butter extraction due to high latex content of the shea kernel apart from solvent extraction method which is mainly used for small laboratory extractions (FAO & CFC, 2005).

a) Traditional boiling extraction

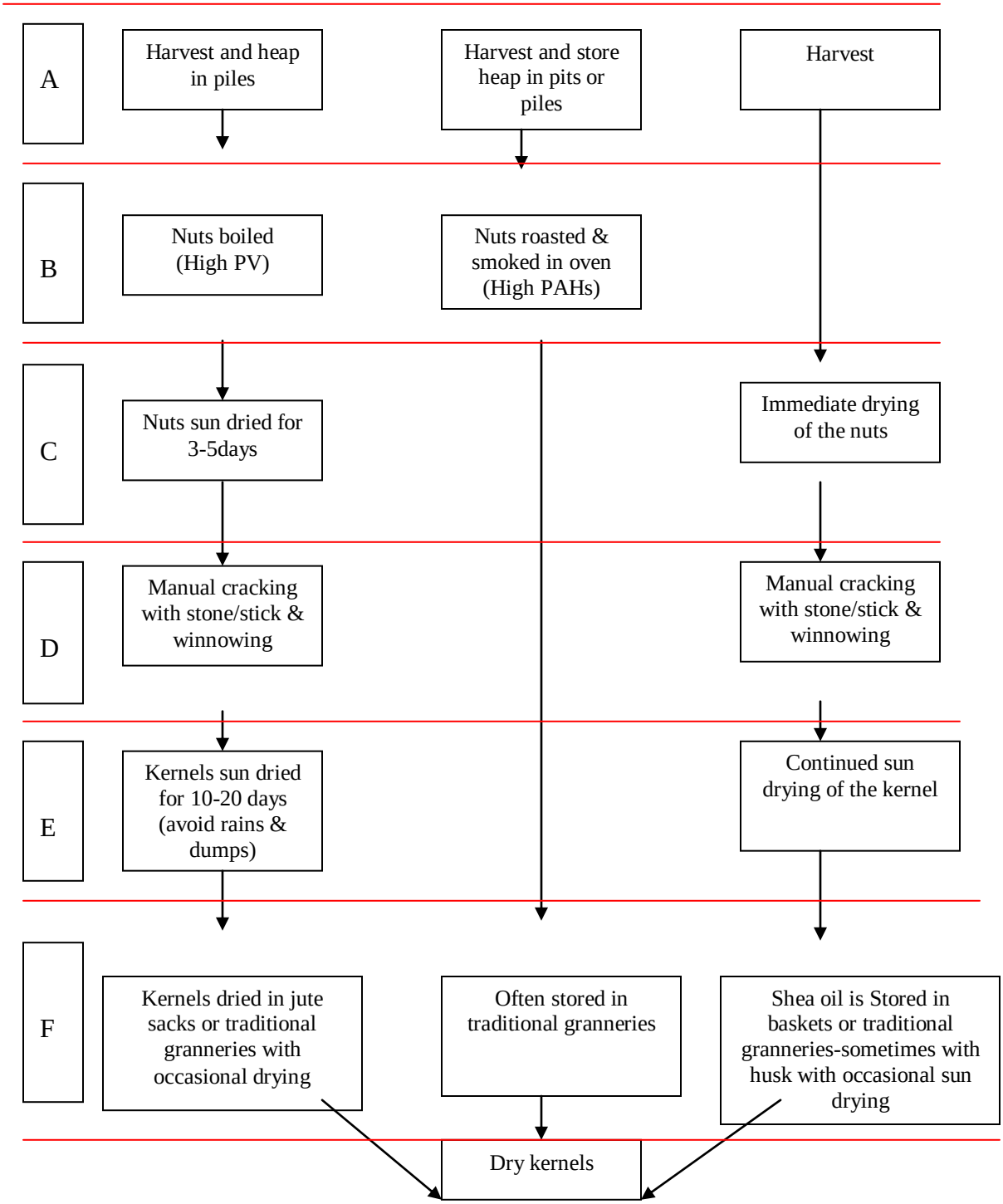
This involves roasting of the kernels with sand and ash before crushing in a local wooden mortar and thereafter milled on grinding stone. The paste is boiled in water until the fat begins to float on surface. After extraction, the butter or oil is transferred into storage plastic or glass containers. According to USAID (2004) and Karin (2004), the traditional preparation or processing of shea oil in East Africa differs from West Africa (Figure 2).

b) Mechanical pressing extraction

As has been reported by FAO and CFC (2005), this processing technique mainly involves the crushing of the shea kernel into coarse particle sizes. The paste is soaked in little hot water before pressing to release the shea butter. The method was developed to improve the efficiency of production of shea butter since traditional boiling method was found to be labour intensive and wasteful (Masters and Puga, 1994).

c) Solvent extraction:

Solvent system is mainly used in laboratory experiment although it is sometimes used for commercial extraction in developed countries. According to FAO and CFC (2005), this method is not usually used in domestic and commercial shea butter extraction due to the high costs involved, environmental problems and lack of technical skills in developing countries.



A- Accumulate, B- Heating, C-Sun drying, D- dehusking. E- Final drying E- storage

Figure 2: Traditional methods of shea kernel processing diagram (USAID, 2004)

Besides, the oil extracted by this method is always cloudy and not suitable for human consumption because of organic solvent residues.

d) Post shea butter extraction process by traditional and mechanical pressing methods

Following extraction by traditional boiling and mechanical pressing methods, shea butter is clarified by wet boiling with water for about 20 minutes at 2:1 ratio of oil to water, cooled and decanted into dry vessel where it is boiled again to remove any water residues (FAO and CFC, 2005).

2.3 Chemical and Nutritional Composition of shea fruits and shea butter

2.3.1 Proximate composition of shea fruit pulp

Although fruits are generally poor sources of proteins and oil, they contain reasonable amounts of carbohydrates, fibre, minerals and vitamins C (Pearson, 1991). According to CRIG (2002), the shea fruit is a seasonal source of calories in the sub Saharan Africa with edible pulp containing 41.2g of carbohydrates, 0.7-1.3% proteins and 196mg/100g vitamin C (CRIG, 2002). A report by Cheman *et al.*, (1999) indicates that while carbohydrates are good sources of energy, proteins can catalyze, regulate, protect and provide energy. Vitamin C on the other hand is essential for normal growth and development of human body.

2.3.2 Mineral composition of shea fruit pulp

Minerals can be classified as either macro or micro. The macro minerals consists of calcium (Ca), sodium (Na), potassium (K) and magnesium (Mg) while micro mineral are iron (Fe), zinc (Zn), selenium (Se), copper (Cu) any many others. In Ghana, the shea fruit pulp has been reported to contain Ca (36mg/100g), Mg (26mg/100g) and iron (1-3g/100g) and others in small quantities (CRIG, 2002, FAO, 2007). According to Maranz *et al.,* (2004) the most abundant mineral in shea fruit is K with values as high as 1300mg/100g in West African countries and 400mg/100g in Uganda. Even other minerals were reported by Maranz *et al.*, (2004) to be higher than those reported by CRIG (2002) and FAO (2007). These mineral compositions across Africa were found to vary by environmental conditions.

The above finding shows that shea fruits are very important in nutrition because of multiple functions of minerals in the human body. According to Hegarty

(1988), Na and K are very important in water balance and normal functioning of the nerves and muscles and absorption of glucose and glycogen while Ca plays a very important function in bones, nervous system, stimulates some hormonal secretions, and activates some enzymes and blood coagulation. Magnesium on the other hand can assist enzymes involved in the synthesis and breakdown of carbohydrates, fats, proteins and synthesis of DNA and RNA while Fe is a constituent of hemoglobin, myoglobin and a number of many enzymes (Yusuf *et al.,* 2007).

2.3.3 Physico-chemical composition of shea oil

The physico-chemical composition of shea oil can be broken into physical parameters and chemical parameters.

a) Physical parameters:

According to Lewis (1990), colour, refractive index and viscosity play an important role in determining the quality of any oil because they give physical specification for description of the oil. While the colour of oil comes from natural colouring matters from α- and β-carotene, xanthophyll and chlorophyll, the refractive index is ratio of light in vacuum to speed of light in the oil under examination and the viscosity is material friction acting within the oil. These are quick parameter for characterization of oils and assessment of the level of purity. Shea butter has been reported to have a pale yellow, cream or grey colour solid at room temperature and refractive index of 1.467 (Adikini, 2002). However, a report by Stryer (1988) indicates that variation in the physical parameters of vegetable oils might be associated with changes in the un-saturated fatty acids due to oxidation, polymerization and isomerisation.

b) Chemical parameters

Acid value, peroxide value, iodine value and saponification value are also important in assessing the quality of natural oils (Choe and Min, 2006). While acid value is a measure of acid hydrolysis that has occurred in the oil or fat, peroxide value is used to quantify the primary oxidative products in the oil due to substantial amount of unsaturated fatty acids (Pearson, 1990). The saponification value on the other hand is weight in milligrams of potassium hydroxide required to hydrolyze one gram of fat or oil while iodine value is an indication of unsaturation in the natural oils. According to UNBS (2004) draft standard for shea butter, the shea butter acid value

is less than 6.0 mg/KOH/kg, peroxide value is less than 10 mEq/kg, saponification value is between 170-190 mgKOH/g and iodine value, $40I_2$/100g. Although Adikini (2002) reported values within the range of UNBS (2004) for shea butter samples from Uganda, higher values were reported by Kapseu *et al.,* 2007 and Tano-debrah and Yoshiyki (1993) for West African shea butter samples. These variations in chemical parameters were attributed to processing, fruit harvesting and kernel storage methods (USAID, 2004).

According to Maranz and Weisman (2004), tocopherols are also chemical parameters that are important in nutrition and cosmetic properties of oils because they act as good anti-oxidants. Their presence also causes oxidative stability of the oil. Although shea butter has been reported to have over 800mg/100g of α-tocopherol in West African shea butter, the shea butter from Uganda has been 29mg/100gm, the lowest in Africa (Maranz and Weisman, 2004). This variation in the α-tocopherol values was associated with environmental conditions. It should be noted, however, that low level of tocopherols can result in a serious decrease in the protective power of any oil against auto-oxidation (Choe and Min, 2006).

2.3.4 Fatty acid profile of shea oil

The five principal fatty acids in shea butter oil (Table 1) are palmitic acid (C_{16}), stearic acid (C_{18}), oleic acid ($C_{18:\ 1}$) linoleic acid ($C_{18:\ 2}$) and arachidic acid ($C_{20:\ 0}$) (Table 1).

Table 1: Reported shea butter fatty acid composition

Parameter (%)	Source		
	FAO (2007)	PROKARITE (2007)	Leakey (1999)
Palmitic acid	5-9	4.7	4.0
Stearic acid	30-41	31.2	46.0
Oleic acid	49-50	56.5	41.0
Linoleic acid	4-5	5.8	7.0
Linolenic acid	-	-	1.0
Arachidic acid	-	1.0	-

The shea oil fatty acid composition is dominated by stearic acid and oleic acid, which together account for 85-90% of the fatty acids (Maranz *et al*. 2004). Adikini (2002) also found that shea butter was dominated with oleic and stearic acids with values of 57% and 30% respectively. The other fatty acids in shea oil include linoleic

(4.3-6.3%), palmitic (3.0-4.4%) cis-vaccenic (0.5-.0.8%) and gadoleic (0.2-.3%). The relative proportion of these oleic and stearic fatty acids is responsible for the differences in shea butter consistency. According to Maranz *et al* (2004), Uganda shea butter have high oleic acid content (50-60%) producing the most liquid shea butter on the African continent. Although a small amount of linoleic acid is in shea butter, it is critical to the stability and flavor of oil.

2.4 Variation of physico-chemical characterics of shea butter

Since there is large dietary consumption of shea butter, variation in physico-chemical parameters becomes a major concern for nutrition and public health experts (Stryer, 1988). A number of steps in post handling processes such as harvesting, drying, storage and oil extraction are responsible in determining the physico-chemical characteristics of shea butter (USAID, 2004). According to FAO & CFC (2005), reducing the moisture content of shea kernel to lower than 8% improves the quality of butter. The low moisture maintains the acid value of shea butter within the edible range in addition to reducing fungal infections on the kernels. To ensure that kernels have low acid value, the W. African countries have adopted a method of parboiling of the fruits prior to depulping as opposed to E. Africa where the kernels are directly sun dried after de-pulping without any boiling (USAID, 2004). In addition to improper drying, poor storage of the kernel can also cause increase in free fatty acid due to moisture uptake resulting in hydrolysis of the fatty acids. Areport by USAID (2004) indicates that shea kernels stored in the open or under humid areas can bring changes in the oxidative parameters of shea butter.

During oil extraction, the exposure of oil with unsaturated fatty acids to oxygen may also increase the deterioration rate due to formation of polycyclic aromatic compounds and polar compounds such as triacylglycerol dimers and triacylglycerols (Warner *et al.,* 1994 and Kapseu *et al.,* 2007). This may result in release of low molecular volatile compounds such as aldehydes, ketones, carboxylic acids, and short chain alkanes and alkenes which are responsible for changes in the physico-chemical characteristics of the oil. According to Boffa, *et al*, (1999) after extraction, exposure of oil to fluorescence light and dark condition during storage increases peroxide value and free fatty acid. A study done by Kapseu, *et al* (2007) found that acid value of shea nuts stored in a refrigerator increased after three

months due to enzyme action leading to high peroxide value.. Post harvest handling practices may also have effect on fatty acids.

According to PROTA (2007), linoleic acid and palmitic acid ratio has been used as indicators for measurement of the extent of fat deterioration. When oils are exposed to oxygen at high temperatures, they tend to under go oxidation (Choe and Min, 2006). The fishy flavor of oil formed during heating is due to oxidation of linolenic acid in the oil. Other volatile compounds such as aldehydes, ketones, benzene which produce un-desirable flavour resulting in the development of rancidity may also be released.

With high level of un-saturation in the oil chances of oxidation may be high (Ferris *et al.*, 2004). Although tocopherols have been used as natural antioxidants, purification and bleaching during processing of the shea oil can lead to losses of alpha-tocopherol. The degradation rate of tocopherol rapidly increases in the presence of molecular oxygen and free radicals (Player *et al.*, 2006). Even if α-tocopherols degrade, high levels can show exceptional storage stability of the oil or fat (King, 1980).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

This study was conducted in the Acholi, Lango, Teso, and West Nile sub regions. Specifically it was carried out in Pader, Lira, Katakwi and Arua districts, respectively (Figure 3). These districts have got well established, reliable shea stands populations and the community highly depend on shea butter oil/fat for both food uses and other benefits.

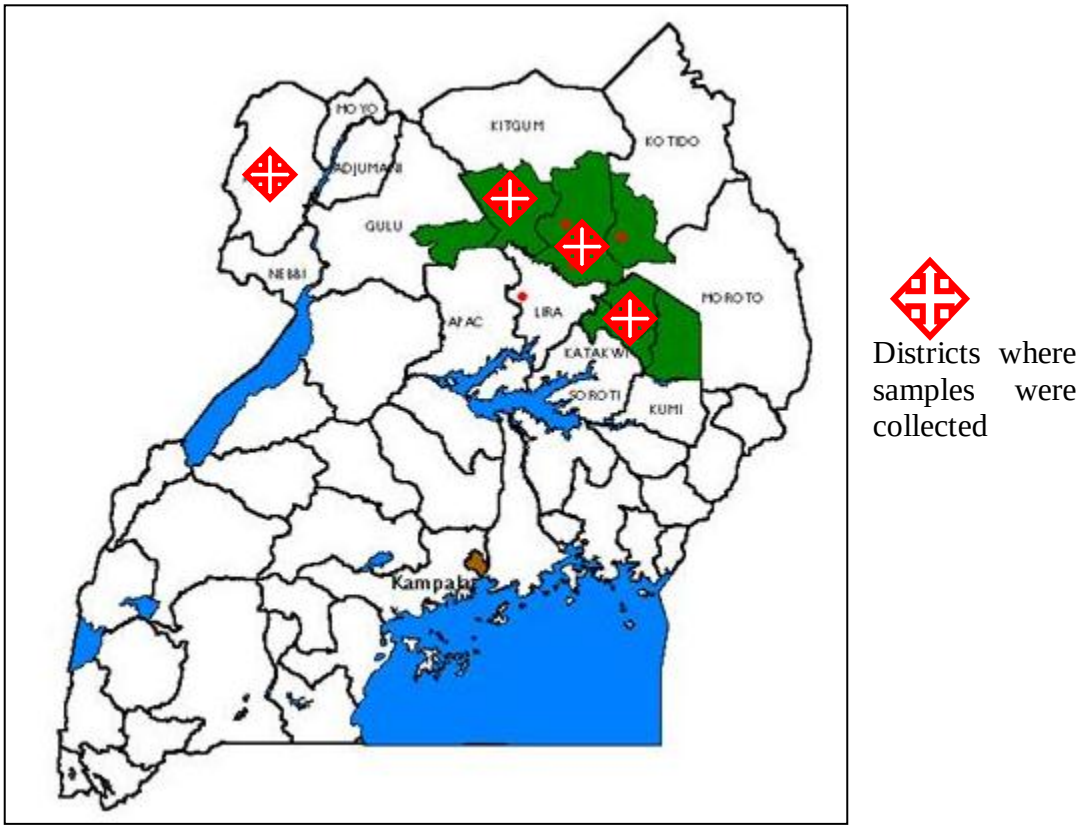


Figure 3: Sub regions where shea fruits were collected

3.2 Methods

The post harvest handling practices of shea butter oil was assessed through a household survey while the chemical and nutritional composition of the shea fruit pulp and shea oil were investigated in the laboratory. The household survey was carried out in selected districts within the shea parklands of Uganda.Fresh fruits

collected from theses districts were processed into pulp, seeds and then shea oil as a control for the assessment of post harvest handling practices. The proximate and mineral composition of the shea fruit pulp and physicochemical characteristics of shea butter oil were compared across the different representative districts.

3.2 Data Collection

3.2.1 Ethno nomenclature and post harvest handling practices of shea butter

Fieldwork was conducted during several visits between July 2007 and January 2008 in the districts of Lira, Pader, Katakwi, Nebbi, Arua and Moyo. The target respondent were local communities in these shea parkland areas. Several data-gathering methods including interviews, semi-structured questionnaires and free-listing were applied to gain a comprehensive picture of the local community knowledge system of the shea tree and post harvest practices. A total of 275 questionnaires were administered. At least focused group discussion with 15 people was also conducted in each district to discuss aspects of post harvest handling of shea butter.

3.2.2 Proximate and mineral composition of the shea fruit pulp

Sample collection: Five kilograms (5kg) of shea fruits were collected from the districts of Pader, Lira, Katakwi and Arua representing Acholi, Lango, Teso and West Nile sub regions. The fruits were collected from different trees in one Sub-county, stored in a cooler at 4^{o}C and transported to laboratory for analysis. Another 0.5 kg traditionally boiled and mechanically cold pressed shea butter were collected from Lira district. The traditional boiled shea butter was collected from one house hold while the cold pressed shea butter was collected from NUSPA/COVOL shea processing plant in Lira district. The methods of extraction or processing were documented and the samples transported to the laboratory where they were maintained at 4^{o}C in the fridge until analyses were completed.

Shea fruit pulp sample preparation: The fruits were sorted and washed with cold tap water before depulping manually to separate the nuts from the pulp. The pulp from the fruit was mashed in a blender and dried in an oven at a temperature between 40 ^{o}C and 50 ^{o}C for 5 days and crushed in an electric grinder into powder (Brooks

Crompton Series 2000).

Shea fruit proximate and mineral sample analysis: The moisture, ash and crude fibre contents were analyzed according to standard methods described in AOAC (1997). Vitamin C was determined by titration with 2, 6-dichlorophenolindophenol (Pearson, 1990). Nitrogen was assayed using Kjeldahl method and the nitrogen content converted to protein by a multiplication factor of 6.25 (AOAC, 1997). Total carbohydrates were determined by difference using a standard method of AOAC (1997). All the proximate analyses were carried out in triplicate and the results expressed as percentage of the sample analyzed. The sample calorific values were estimated (in kcal/g) by method adopted from Yusuf *et al.*, (2007).

Vitamin C: In order to prepare the extract solution, phosphoric acid (15g) was mixed with acetic acid (40ml), water (100ml) and then made to 500ml with water. The ascorbic acid standard solution was prepared by dissolving L-ascorbic acid (100mg) in 100ml of water while the indophenol solution was prepared by dissolving 50mg of 2,6 dichlorophenolindophenol (DCPIP) in 450ml of water containing 42mg sodium bicarbonate which was later diluted to 500ml, filtered and kept in brown reagent bottle.

The standard vitamin C solution (2ml) was pipetted into a 50ml conical flask containing 5ml of extracted solution and titrated with DCPIP solution until the pink colour that persisted for about 10 seconds was obtained. The concentration of Vitamin C was then calculated in 1ml DCPIP solution. The fruit pulp sample (1gm) was blended with 100ml of extracted solution and filtered in porous filter paper. The fruit extract solution (10ml) was then pipetted into 100ml conical flask and titrated with DCPIP until the pink colour persisted for 10 seconds. The vitamin C results were expressed as mg / 100g (Pearson, 1990).

Fruit moisture content: The fresh fruit pulp (0.20-0.30g) was weighed into a dry porcelain dish with a known weight. The sample was dried in vacuum oven at a temperature of 110^{o}C for 4 hours, cooled in a desiccator and weighed. The drying and weighing was repeated twice until there was no difference in the two weights. The moisture content was calculated following the method of AOAC, (1997).

$$\%.Moisture\ content = \left(\frac{Weight\ of\ wet\ sample - wet\ weight\ ofsample}{Weight\ of\ wet\ sample} \right) \times 100 \quad \text{.....(1)}$$

Crude oil content: The dry fruit pulp (15g) was extracted with *n*-hexane solvent using soxhlet apparatus for 6 hours. The crude oil extracted was concentrated in a rotary evaporator and dried by heating in a vacuum oven at 50^{o}C for one hour. The percentage crude oil content was then determined gravimetrically (AOAC, 1997).

$$\%.crude\ oil = \left(\frac{Mass\ of\ extracted\ oil}{Mass\ of\ dry\ sample} \right) \times 100 \text{ ……(2)}$$

Total ash: The dry fruit pulp sample (0.20-0.30g) was placed in a dry porcelain dish and heated progressively for 6 hours at 550^{o}C until, grey -reddish ash was obtained (AOAC, 1997). The sample was cooled in a dessicator, weighed and total ash calculated using the formula:

$$\%.Total\ ash = \left(\frac{(Mass\ of\ dish + ash) - (Mass\ of\ dish)}{(Mass\ of\ dish + test\ sample) - (Mass\ of\ dish)} \right) \times 100 \text{ ……(3)}$$

Crude fibre: About 2-3g of shea fruit pulp powder was transferred into a 200ml labeled beaker after which 1.25 % Sulphuric acid (50 mls) and distilled water (150 mls) were added. The sample mixture was then boiled for 30 minutes under reflux flask and later treated with 1.33% potassium hydroxide (50 mls) and 150ml water. The solution was re-boiled again for 30 minutes and refiltered using vacuum crucible filtration system. The sample in the crucible was rinsed with water followed by acetone. The samples were put into a pre-weighed crucible and transferred to the oven to dry for 4 hours, cooled in dessicator and weighed .The weighed sample was ashed in the furnace set at 660 ^{o}C for 5 hours until it became grey ash which was cooled in the desicator and weighed (AOAC, 1997). The weight of ash was then calculated as follows:

Weight of Ash = Weight of the crucible and the Ash – Weight of the crucible.

The crude fibre was determined using a formula:

Weight of the fiber = Weight of the fiber and the ash – Weight of ash.

$$\%.crudefibre = \left(\frac{Weight\ of\ crudefibre}{Original\ weight}\right) \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(4)$$

Crude proteins: The dry shea fruit pulp powder (0.20-.0.30 g) was placed in boiling tube and a 0.5g mixture (catalyst; titanium dioxide and copper sulphate) was added. The mixture was digested with concentrated sulphuric acid (5ml) for 2 hours in fume hood until the solution became clear to light green. Distilled water (200ml) was added to the solution and allowed to cool. Sodium hydroxide (50%) was also added without agitation. The flask was then connected to the distillation bulb with the tip of the condenser immersed in a standard acid solution containing 5 drops of the indicator. The flask was then heated to release ammonia into the indicator solution. The excess standard acid in the distillate was titrated with 0.1N standard NaOH. The conversion factor of 6.25 was used (AOAC, 1997) and % of Nitrogen calculated as below.

$$\%.Nitrogen = \left(\frac{(ml\ of\ std\ acid \times N\ of\ acid) - (ml\ of\ std\ NaOH \times N\ of\ NaOH \times 1.4007g}{Weight\ of\ sample}\right) \times 100$$

$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(5)$$

Total carbohydrates: Total carbohydrates were determined by difference using the method in AOAC (1997) :

Total carbohydrates = [100- (Moisture content- Crude lipids- Cude proteins)]

Mineral analysis: Two (2) g of dry shea fruit pulp powder was weighed into a clean boiling tube. Distilled water (5.0ml) and concentrated nitric acid (25ml) were added and mixed by shaking gently. The mixture was then refluxed over a water bath at 90^{o}C for 4 hours, cooled and 10ml of concentrated perchloric acid added. The tubes were again refluxed over a water bath at the same temperature for 1hour and later cooled to room temperature. Concentrated HCl (2ml) was then added to the sample, made to 100ml with distilled water and filtered. Standard solutions of different

minerals earlier prepared in the concentrations of 0.125, 0.25, 0.50, 1.00 ppm were used in the calibration. The samples were then analyzed with Atomic Absorption Spectrophotometer model AA-63000 using graphite furnace, Shimatzu, Japan.

3.2.3 Physico-chemical characteristics and fatty acid profile of shea butter

Shea nut sample preparation: The seeds/kernels were also dried at the same time in the oven for 5 days at the same temperature as the pulp. The dry nuts were dehusked manually using a metallic rod to obtain shea kernels that were further dried for another 5 days at the same temperature. The dry kernels were later crushed into powder using an electric grinder machine (Brooks Crompton series 2000), packed in a low dense polyethylene (LDPE) bag and stored in a dry cupboard till oil extraction was complete (Kapseu *et al.*, 2007).

Oil extraction: The crushed kernels were extracted with *n*-hexane solvent for 5 hours using soxhlet apparatus at 60^{o}C. The butter/oil from the kernel was concentrated using a rotary evaporator and later dried by heating in a vacuum oven at 50^{o}C for 60 minutes. The percentage of the crude oil was determined gravimetrically (AOAC, 1997). The extracted oil samples were stored in the refrigerator at 4^{o}C until analysis was completed.

The physico chemical parameters involved analysis of both physical and chemical parameters of the shea oil.

Physical parameters: The colour, refractive index and viscosity of shea butter were analyzed using methods recommended by AOAC (1997). The analyses of colour was carried out using a Lovi bond apparatus (Tintometer model E, S. No. 5064E), viscosity using a viscometer (BROOKFIELD DV-11+Pro, USA) at 34-35^{o}C and the refractive index using a refractometer (Bellingham + Stanley (B^{+}S), No. A86006).

Chemical parameters: Acid value, saponification value, peroxide value and iodine value of shea butter oil were analyzed using standard methods of analysis described in AOAC (1997). The α-tocopherol was determined by High Performance Liquid Chromatography (HPLC), Perkin Elmer, USA, using a standard from Sigma – Aldrich, USA CAS 59-02-9 (AOAC, 1997); while the fatty acid profile was

determined using trans esterification with anhydrous methanol containing 2M HCl for 2 hours at 90 ^{o}C in an oven.

Colour: Shea butter/oil sample (10ml) melted at 35 ^{o}C in water bath was placed in a cuvet and analyzed using a Lovi bond –Tintometer model E, S. No. 5064E, England. The colours of red, yellow and blue units were adjusted until a perfect colour match was obtained. The unit value of the colour with the lowest unit was subtracted from the colours leaving two units which were then used to describe the colour of the sample (AOAC, 1997).

Refractive index: Shea butter/ oil sample (0.5g) was melted at 35^{o}C in water bath and the refractive index analyzed directly using Bellingham + Stanley refractometer (Model No. A86006).

Viscosity: Shea butter sample (300ml) melted at 34.5 ^{o}C was placed in 600ml beaker and the viscosity was determined using BROOKFIELD DV-11+Pro programmable viscometer made in USA S.No. TR P6514911, model LVDV-11+P by inserting the spindle down to a depth of 1cm into the oil sample. The analysis was carried out with a spin code 61, RPM 30 at a temperature of 34.5^{o} C. The viscometer was first standardized using viscosity standard fluid from brook field and the values read in centipoises (cP). The formula used for the calculation is

$$Viscosity = \left(\frac{100 \times TK \times SMC \times Torque}{RPM} \right) \times 100 \quad \text{.....(6)}$$

Where:

RPM =Current viscometer spindle speed,

TK= Viscometer torque constant from (Appendix D (Table D1)-Visco meter manual)

SMC= Current spindle multiplier constant Appendix D (Table D1)-Visco meter manual)

Torque = Current viscosity torque (%) expressed as a number between 0-100

Acid value: Diethyl ether (25ml), ethanol (25ml) and 1% phenolphthalein (1ml) were carefully mixed and neutralized with 0.1M NaOH. Shea butter (2g) was

dissolved in the neutral diethyl ether, ethanol and phenolphthalein solution. The solution was then titrated with 0.1M NaOH until a pink colour that persisted for at least 15 second was obtained. All the analysis for each sample was done in triplicate (AOAC, 1997). The calculation was as follows:

$$Acid\ value = \left(\frac{Titration\ (ml) \times 5.61}{Weight\ of\ sample}\right) \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

Peroxide value: Shea oil samples (2g) was weighed into a 250 ml stoppered conical flask and dissolved in chloroform (10ml) by swirling. Glacial acetic acid (15ml) and fresh saturated aqueous potassium hydroxide solution (1ml) was added. The flask was stoppered and shaken for 1 minute and placed in dark room for 5 minutes. Distilled water (75ml) was added and titrated (V) with 0.01M sodium thiosulphate solution using 1% starch indicator (1ml). A blank determination was done and results recorded (titration $=V_o$). All the analysis for each sample was done in triplicate and peroxide value calculated using the formula:

$$Peroxide\ value = \left(\frac{(V - Vo) \times 0.01}{Weight\ of\ sample}\right) \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(8)$$

Saponification value: Shea butter/oil samples (2g) was weighed into a conical flask and 25ml of ethanolic potassium hydroxide added. The solution was refluxed in boiling water bath for 1 hour while being shaken frequently. One ml of phenolthalein indicator was added to the hot solution and titrated immediately with 0.5M hydrochloric acid (sample titration= a ml). A blank test was done and results recorded (blank titration = b ml). All the analysis were done in duplicate (AOAC, 1997) and the saponification value calculated as:.

$$Saponification\ value. = \left(\frac{(b - a) \times 28.05}{Weight\ (g)\ of\ sample}\right) \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(9)$$

Iodine value (Hanus method): The hanus iodine reagent was prepared by dissolving iodine (13.2 gm) in glacial acetic acid (1litre) with the help of heat. The solution was cooled and 3 ml of bromine added. The hanus iodine reagent was then kept in a brown bottle until the analysis was complete. Shea butter (2g) was weighed into a 500ml conical flask and 10ml of chloroform added. By use of a pipette 25ml of hanus iodine was added and left to stand in the dark for 30minutes with occasional shaking. After this 15% potassium iodine was added, shaken thoroughly and distilled water (100ml) added to rinse down any iodine on the stopper.

The solution was then titrated with 0.1N sodium thiosulphate until a yellow solution turned almost colourless (titration = S ml). Three drops of starch indicator (1%) was added towards the end point and titration was continued until the blue colour turned colourless. A blank determination was done and results recorded (titration = B ml). All the analysis were done in duplicate (AOAC, 1997) using the formula.

$$Iodine\ value = \left(\frac{(B-S) \times 0.1 \times 12.69}{Weight(g)\ of\ \ sample} \right) \times 100 \quad \text{.....(10)}$$

Fatty acid profile: This was analysed by trans-esterification method reported by Lepage and Roy (1986) and modified by Joensen and Grahl-Niesen (2001). Shea butter sample (7.0 -10.0 mg) was transferred to 15ml thick walled glass tubes. After addition of 1ml anhydrous methanol containing 2M HCl and exchange of atmosphere in the tubes with purified nitrogen gas, the tube was securely closed with teflon-lined screw caps. Subsequently the tube was placed in an oven for 2 hours at 90^{o}C for complete methanolysis.

After cooling to room temperature, the tube was opened and the methanol evaporated down to about 0.5 ml by stream of nitrogen gas to make methyl esters less soluble in methanol phase and 0.5ml distilled water was added to the methanolised lipid fraction. The cap of the tube was tightened and mixed for one minute followed by centrifugation to separate the phases. Using a pipette, the upper hexane layer containing fatty acid methyl esters was transferred carefully to the vial. The water–methanol phase was extracted twice using 1 ml n- hexane.

One microlitre (1µl) of the mixed hexane extracts was injected splitless (the split opening after 4ml) in Elmer 8500 gas chromatograph equipped with a flame –

ionization detector (FID) on the 25m x 0.25mm (1.d.) column coated with polyethylene glycol (PEG) as a stationery phase of 0.2µm thickness (CP-WAX 52CB Chrompack) and the mobile phase was hydrogen at 20psi. The injector and detector temperatures were set at 260^{o}C and 330^{o}C, respectively. The oven was programmed as 90^{o}C for 4 minutes before cooling for the next run. The chromatographic peaks were identified by comparison with the standard chromatograph of the mixture of 20 fatty acids methyl esters, GLC reference standard 68D Nu-Check –Prep (Elysian , Minn., USA) (Figure: 4). The components eluting from the column were detected by FID whose output signal was captured and recorded in computer with Turbochrome 4 soft ware data system.

To monitor the performance of the column in the gas chromatograph, the standard mixture of the fatty acid methyl esters were chromatographed at regular intervals for each tenth sample (Appendix IV). The amount of each fatty acid in the sample was expressed as % of the sum of all fatty acids in the sample using the formulae below:

$$\%.fatty.acid = \left(\frac{Fatty.acid.peak.area}{\sum total.fatty.ac.id.peak.areas} \right) \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

α - tocopherols: This was determined by High Performance Liquid Chromatography (HPLC), Perkin Elmer using standard methods from AACC (1989). A calibration curve was first prepared using a standard alpha tocopherol from Sigma –Aldrich, USA, CAS 59-02-9 (Figure 5). One mililitre of the working standards (20ppm, 40ppm, 60ppm, 80ppm, 100ppm) were pipetted into separate conical flasks and methanol (30ml), 10% ascorbic acid solution (3ml) and 50% KOH (4ml) were added, shaken and sonicated for 10 minutes. The solutions were saponified for 2 hours in the conical flask under reflux at a temperature of 40-50^{o}C in the dark. The contents were cooled in the conical flask, transferred into a separating funnel and washed with 10ml distilled water till all the material were transferred.

The saponified extract was extracted consecutively three times with 70ml, 40ml and 40ml of petroleum ether respectively, by shaking for 5 minutes. The ether extract were combined and 100ml of distilled water added and shaken for 5minutes

three times until it was neutral to phenolthelein indicator (AACC, 1989). The ether extract was then passed through anhydrous sodium sulphate and evaporated to dryness using water bath at 70^{o}C. The residue was dissolved in 3ml of distilled methanol and 20µl was injected into the HPLC. The samples were separated in a column (C8, Perkin Elmer, 250mm x 4.0mm). The solvent system employed was methanol-water (85:15 v/v). Three grams of each oil sample was treated the same way as the standards.

The prepared samples were separated using brownlee analytical C8 column, Perkin Elmer (250mm x 4.0mm) by employing Methanol-Water (85:15 v/v) with a flow rate of 1.5 ml/min. The value of α- tocopherols in the standard were detected by the UV detector set at 284 nm. The samples of shea butter (2-3g) were treated the same way as the standard. The α-tocopherols in the sample were identified by comparing their retention times with those of known α -tocopherol standard. The values were then calculated as mg/100g from the calibration curve (AACC, 1989)

3.3 Data Analysis

3.3.1 Ethno nomenclature and Post harvest handling practices of shea butter

The data from questionnaires were edited, coded and entered into SPSS computer programme. The frequency of items mentioned across the lists in the questionnaires was calculated by counting the total number of reports of each item among the respondents. It is important to note that the frequency of mentioning is a good measure for salience, although it does not consider the item's position within the list. Frequency tables, histograms, logistic regressions were used in the analysis.

3.3.2 Proximate and mineral composition of shea fruit pulp

Results for proxime and mineral compositin were entered into Micro soft Excel spread sheet and the data summarized into mean and standard deviation. Analysis of Variance (ANOVA) was carried out to assess the variation of each parameter within the regions (Sokal and Rolf, 1994).

3.3.3 Physico-chemical characteristics and fatty acid prfile of shea butter

Results for physico-chemical characteristics and faty acid profile were entered into Micro soft Excel spread sheet and the data summarized into mean and standard

deviation. Analysis of Variance (ANOVA) was carried out to assess the variation of each parameter within the regions (Sokal and Rolf, 1994).

CHAPTER FOUR

RESULTS

4.1 Ethno-Nomenclature of the shea tree (*Vitellaria paradoxa*) and its products in the shea zones of Uganda

4.1.1 Socio-demographic characteristics of respondents from the shea zones

The socio-demographic characteristics of respondents are presented in Table 2. Majority of the respondents among Acholi, Lango, Madi and Lugbara ethnic groups were men as opposed to the Alur and Iteso ethnic groups. The respondents interviewed were aged between 19 and 60 years old and their main occupation was subsistence farming. Very few respondents were engaged in normal trade.

Table 2: Socio-demographic characteristics of respondents from the shea producing zones

Variable	% Response					
	Acholi	Lango	Iteso	Madi	Alur	Lugbara
Sex						
Male	72	69	47	02	37	63
Female	28	31	53	38	63	37
Age						
< 18years	00	09	03	13	00	04
19-37 years	43	37	44	53	50	38
38-56 years	42	46	44	34	42	52
>56 years	15	08	09	00	08	06
Occupation						
Subsistence farming	89	85	87	85	95	90
Trade	11	15	13	15	05	10

4.1.2 Ethno-names of the shea tree in the shea parkland areas of Uganda

The ethno-naming of the shea tree varied widely among the studied ethnic communities in the shea parklands (Table 3). For instance, the Acholi ethnic group called the shea tree *yaa, yao*; the Alur called it *yen yao, danyu, awa*; the Lango called it, *yao and* the Iteso as *ekuguru* while the Lugbara called it *awa* and the Madi

ethnic group called it *awa, awa pati* and *awa kwee*. The ethno-name *yao* was common to the Acholi, Alur and Lango while *awa* was common to the Lugbara and the Madi ethnc groups. The meanings behind such naming was, however, not sought in this study.

4.1.3 Ethno-names of the shea tree products in the shea parkland areas of Uganda

The naming of the shea tree products also varied widely among the ethnic groups. For example, among the Acholi ethnic group, the shea fruit was also called by different names such as *odua, eduu, kitigu* and *kiduu (*Table 3). The Iteso called it *akungur, adanyoi* and *odu* while the Lango people called the shea fruit *adu, adanyo or kom yaa*, (Table 4).

Table 3: Ethno-names of the shea tree in the shea parkland areas of Uganda

Ethnic groups	Ethno-names of shea tree
Acholi	*Yaa, yao*
Alur	*Yen yao, awa, danyu*
Iteso	*Ekuguru*
Lango	*Yao*
Lugbara	*Awa*
Madi	*Awa pati, Awa kwee*

The shea nut was also known by various names. The Acholi for instance called it *yao magolo or yaa magolo* and the Lango called it *yao agulu* while the Alur ethnic group called the nut as *pok yao, apoka yao, awakorongo, den yao* or *pok sundry* (Table 4). The ethno-names of other shea tree products such as shea kernel and the shea oil are also presented in Table 4.

Table 4: Ethno-names of the shea tree products in the shea parkland areas of Uganda

Ethnic groups	Ethno-names of shea tree products			
	Shea fresh fruit	Shea nut	Shea seed kernel	Shea oil
Acholi	*Odu, odua, eduu, kitigu, kiduu*	*Yao magolo, yaa magolo*	*Yaa nyige, nying yaa,yaa magolo yaa koro*	*Moo yaa, moo yao*
Alur	*Dany yao, danyo, odanyo, adu, awa adu*	*Awakorongo, den yao, pok yao, yaa sundri*	*Nyige yao, aweki*	*Moo yao, awa odu, odu omoo*
Iteso	*Akungur, adanyoi, odu*	*Akunguru*	*Elemut, akungur Kiwee*	*Akungur, alinyo moo yaa*
Lango	*Adu, adanyo, kom yao*	*Yao, yao agulu*	*Yao okoro, yao*	*Moo yao*
Lugbara	*Awodu, aswadi, awadu, odu, owodu, aweki*	*Aweki, awasodri, awa ongolo awaongorobo awakorongo, awakini, iki ikiya*	*Sundri, nyige, den yao, awa gili, awa ogiri,awaikiki awasodi*	*Odu, oduni, omo, ikuya awadu, awaa adu, ikiya*
Madi	*Awa udu, awa adu, aweki, awasodi*	*Awa echwi, awa ekwi, awa gili awa boroso, awa obo*	*Awa boroso, awa ekwi, ugalera, awa opalarekwi awaikiki, awa gili awa ogiri, awa opkolo, aweki*	*Awa odu, awa adu*

4.2 Post harvest indigenous knowledge and practices of shea butter products in the shea zones of Uganda

4.2,.1 Post harvest handling of shea fruits

A majority of the collectors were women with 57% of the respondents reporting the time for collection to be in the morning and afternoon hours (Table 5a). Over 89% of the respondents reported that the months for peak collection of shea fruits in Uganda were between April and June and only 10% of them reported the months of July and September. Less than 1% of the respondents reported having harvested shea fruits in the months of January to March in the districts of Katakwi and Arua, respectively.

Table 5a Shea fruit collection/harvesting in study areas of Uganda.

	% Response N=275						
Post harvest practices of shea fruits	Pader	Katakwi	Lira	Moyo	Nebbi	Arua	Total
Category of collectors							
Women only	10.2	5.5	10.2	2.5	0.0	7.6	**36.0**
Children and Women	2.5	3.8	2.1	6.4	5.9	2.5	**23.3**
Children only	0.4	4.7	2.5	2.5	0.8	6.8	**17.8**
Men only	4.2	1.3	3.4	0.4	0.0	0.0	**9.3**
Whole family	0.0	0.4	0.4	1.3	0.0	3.0	**5.1**
Men and Women	0.8	0.0	0.8	0.0	0.0	0.0	**1.7**
Men and Children	0.4	0.0	0.4	0.0	0.0	0.0	**0.8**
grandparents	0.0	0.4	0.0	0.0	0.0	0.0	**0.4**
Harvesting time							
Morning & Afternoon hours	13.2	3.7	12.1	9.9	4.4	14.3	**57.5**
Morning hours only	3.3	12.1	6.2	4.0	0.4	6.6	**32.6**
Afternoon hours only	0.0	0.0	1.1	0.0	0.0	0.0	**1.1**
Evening hours only	0.4	0.0	0.0	0.0	0.0	0.0	**0.4**
Other methods of shea fruits collection other than under parent shea trees							
Climbing the parent shea tree	0.0	4.0	3.3	8.0	2.2	6.9	**24.5**
Under non shea trees	0.0	3.3	1.1	1.8	1.1	2.2	**9.5**
Harvesting season							
April –June	14.8	14.0	21.0	15.1	4.4	19.9	**89.3**
July-September	2.6	2.6	0.7	0.0	3.0	1.1	**10.0**
January- March	0.0	0.4	0.0	0.0	0.0	0.4	**0.7**
Identification of ripe fruits							
Soft texture	11.7	9.1	5.5	2.9	4.0	11.7	**44.9**
Sweet taste	9.1	2.6	1.1	3.3	0.0	1.1	**17.2**
fruit smell	0.4	1.1	6.9	2.2	0.0	0.7	**11.3**
Fruit colour	1.1	0.4	2.2	0.7	0.0	1.1	**5.5**
Signs of eaten by birds or bats	0.0	0.0	1.8	0.7	0.0	1.1	**3.6**

Although shea shea fruits were mainly collected under parent shea trees, about 25% of the respondents reported that they climb the shea trees and shake down the ripe

fruits while only 10% reported that they had collected shea fruits from under other trees which were shea trees. Almost 45%, 17%, 11% and 6% of the respondent reported that they use texture, taste, smell and colour respectively to identify ripe shea fruits (Table 5a).

Over 40% of the respondents reported that shea fruits for consumption were mainly sorted by removing rotten, depulped, immature, non greenish yellow colour and small sized fruits. While 45% of the respondents reported depulping of shea fruits by hand peeling, over 38% reported that pulps were eaten or scraped with a knife, crushed fruits in sack, dryied off together with the pulp, less than 10% reported that shea pulps were fermented and washed off with water.

Table 5b: Shea fruit preparation and uses in the study area

	% Response N=275						
Post harvest practices of shea fruits	**Pader**	**Katakwi**	**Lira**	**Moyo**	**Nebbi**	**Arua**	**Total**
Sorting Criteria							
Rotten fruits	2.2	4.7	5.5	0.7	0.4	0.0	**13.5**
De-pulped fruits	0.0	1.1	1.8	1.1	0.0	5.1	**9.1**
Fruits eaten by birds/bats	0.0	4.7	0.4	0.4	0.0	1.5	**6.9**
Immature fruits	0.7	1.8	0.4	0.4	0.0	0.7	**4.0**
Fruits not greenish- yellow in colour	0.7	1.1	0.4	0.7	0.0	0.4	**3.3**
Fruit with no sweet taste	0.0	2.2	0.0	0.4	0.0	0.0	**2.6**
Small sizes fruits	0.0	0.0	0.0	0.0	0.0	1.5	**1.5**
De-pulping							
Peeling or smashing the fruit with hands	13.1	4.4	17.5	7.7	1.1	1.1	**44.9**
Eating the fruit pulp	3.3	8.8	3.3	6.2	6.9	10.2	**38.7**
Scraping the pulp with a knife	0.0	0.4	0.4	1.8	5.1	11.7	**19.3**
Crashing the fruits in the sack	4.4	2.6	0.0	3.6	0.0	1.8	**12.4**
Drying and rubbing off the dry fruit pulp	2.2	2.6	0.7	1.5	0.0	0.4	**7.3**
Rotting or fermenting the fruits	0.4	1.5	0.7	2.2	0.0	3.3	**8.0**
Washing off the fruit pulp with water	1.8	0.0	0.4	1.8	0.0	0.0	**4.0**
Fruit storage areas							
House floor	0.7	5.1	4.0	3.3	3.3	3.3	**19.7**
Ground under the granary	0.4	1.5	1.1	0.0	1.1	4.4	**8.4**
On the house veranda	0.7	0.7	2.6	2.2	0.7	0.7	**7.7**
In the kitchen floor	1.5	0.7	0.4	2.6	0.0	1.1	**6.2**
In the dug hole on the ground	0.0	0.0	0.7	0.0	0.0	1.8	**2.6**
Uses of shea fruits							
Eaten as fresh fruit	16.1	21.2	13.5	19.3	13.9	7.3	**90.9**
Sold for income	1.8	2.2	1.5	2.6	3.6	0.4	**12.0**
Animal feed	1.1	2.6	0.7	2.6	0.7	0.4	**8.0**
Processed and eaten as dry fruit powder	5.1	0.0	0.4	0.4	0.0	0.0	**5.8**
Used as manure in gardens	0.0	0.0	1.8	2.2	0.4	0.0	**4.4**

About 46% of the respondents reported that they usually store shea fruits on house

floors, on the ground under granary, on house veranda, on kitchen floor and dugged holes in the ground. Over 90% of the respondent reported eating the fruit pulp while less than 5% reported that shea fruits were sold for cash income, fed to animals, processed into powder or used as manure in the gardens (Table 5b).

4.2.2 Shea nut and kernel handling plus storage

Following collection of shea fruits and depulping, the transformation of shea nuts into shea kernels was reported to involve drying and de-husking. The main method for drying of shea nuts and shea kernels was sun drying reported by 88.3 % of the respondents while baking of the shea kernels was reported by only 7.3% of the respondents (Table 6).

While about 40% of the respondents reported having used sisal or polythene sacks other than gourds for storing the dry shea kernels, over 36% and 27% reported the shelf life of shea oil to be between 9-12 months and over 12 months, respectively. Although only less than 21% of the respondents reported the shea oil shelf life to be between 5-8 months, over 11% of them reported it to be 1-4 months (Table 6).

Apart from using shea kernels for shea butter extraction, several other uses such as selling for cash income, burning as mosquito repellents and use as preservative for traditional cereals, trapping bait and traditional medicine were reported by 44.5%, and 1.5% of the respondents respectively (Table 6).

4.2.3 Shea oil extraction, packaging and storage

Over 90% of respondent were involved in shea oil extraction and about 66% of them reported that the yield of shea oil traditionally processed was 30% or less. While 17.9% of the respondent were of the view that the yield of shea oil could even be more than 60%, only 11.2% of them reported shea kernels could yield between 31-59% (Table 7).

Over 85% of the respondents reported the major colours of indigenous traditionally processed shea oil to be brown, red and yellow. While 50% of the respondents reported brown colour, 21% and 14% of them respectively reported red and yellow colours.

Table 6: Post harvest handling practices and use of shea nut / kernel in selected shea districts in study area

	% Response N=275						
Post harvest practice and use	Pader	Lira	Katakwi	Arua	Moyo	Nebbi	Total
Drying method of nuts							
Sun drying	17.2	20.8	11.7	19.3	12.4	6.9	**88.3**
Roasting or baking	1.1	1.1	3.3	0.4	1.5	0.0	**07.3**
Storage containers							
Sisal/Polythene sacks	6.9	12.4	2.2	9.9	6.9	1.8	**40.1**
Clay pots	1.1	1.1	3.3	2.9	2.9	0.7	**12.0**
Low Dense Polyethylene bags	0.4	1.8	4.4	1.8	0.0	0.7	**9.1**
Woven baskets	1.1	1.5	0.7	2.6	1.1	0.0	**6.9**
Drums (plastic or metallic)	0.4	2.6	0.4	0.7	0.4	2.6	**6.9**
High dense plastic buckets	0.0	0.4	1.8	0.0	1.8	0.0	**4.0**
Gourds	0.4	0.0	1.5	0.0	0.0	0.0	**1.8**
Storages areas							
House (hut) floor	8.4	3.3	5.5	8.4	6.9	6.6	**39.1**
Granary floor	8.0	6.2	3.3	6.2	0.0	2.6	**26.3**
Kitchen floors & hanging in kitchen	1.9	0.4	2.2	0.0	3.7	0.0	**8.1**
Shelf life of the nuts (Months)							
9-12	4.9	8.2	3.7	12.3	3.0	4.5	**36.6**
More than 12	4.1	9.0	1.9	3.7	7.1	1.9	**27.6**
5-8	6.0	4.1	5.2	3.4	1.5	0.4	**20.5**
1-4	2.6	0.4	4.5	2.6	1.9	0.0	**11.2**
Other uses of the shea kernel apart from shea oil							
Sold for income	13.5	10.6	4.0	5.8	7.7	2.9	**44.5**
Mosquito repellant/insecticide	1.9	0.8	5.4	0.4	0.4	0.0	**8.7**
Decorations or art work	3.6	0.4	0.7	0.7	0.4	0.7	**6.6**
Fuel	0.0	1.8	0.0	0.4	0.7	2.6	**5.5**
Mosquito larvicide's	0.0	0.0	2.9	0.4	0.7	0.0	**4.0**
Cultural taboos	0.0	0.0	0.7	1.1	1.5	0.0	**3.3**
Local salt (ash)	1.1	0.4	0.4	0.4	0.0	0.0	**2.2**
Preservative for traditional meals	0.0	0.0	1.5	0.7	0.0	0.0	**2.2**
Trapping animals	0.0	0.0	1.5	0.4	0.0	0.0	**1.8**
Medicine for wounds	0.0	0.0	0.0	0.0	1.5	0.0	**1.5**

A majority of the respondents reported that they use plastic containers and less than 6% used a tin for storing shea oil. While over 78% of the respondents reported that shea oil in these containers are stored in either house floors or hanged in houses, only 8.8% of them reported that they usually keep shea oil in storage containers on kitchen floors or hanged up in the kitchen. About 42% of the respondents reported stored shea oil to have a shelf life of between 2-3 months, 29% and 15.3 % of them were of the view that shea oil could have a shelf life of less than one and more than 4 months, respectively (Table 7).

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The major reported uses of shea oil included uses as food, selling for earning cash income, cosmetics, frying food, baking, lubricantion, traditional medicine, soap making and blessing during cultural ceremonies reported by 57.7%, 52.2 %, 455, 32%, 8% and less than 6% of the respondents respectively. The other uses of the shea cake reported by the respondents were uses as local salts, mosquito repellant, vanish, preservative, manure, smearing hut floors, lubricant, mosquito larvicides, traditional medicine, fuel, animal feed and cleaning calabashes (Table 7).

Table 7: Post harvest handling practices and use of shea oil in the study area.

	% respondent N=275						
Post harvest practice and use of shea oil	Pader	Lira	Katakwi	Arua	Moyo	Nebbi	Total
Oil yield in traditional processing (L/kg)							
0.00-0.30 (≤30%)	10.4	14.9	13.8	13.8	7.8	5.2	**66.0**
More than . (>60%)	5.2	1.9	0.4	6.3	3.7	0.4	**17.9**
0.31-0.60	1.5	3.0	2.2	1.1	1.9	1.5	**11.2**
Colour of quality shea oil							
Brown	8.0	9.0	11.0	10.0	14.0	3.0	**50.0**
Red	2.0	8.0	1.0	5.0	1.0	4.0	**21.0**
Yellow	1.0	5.0	6.0	9.0	3.0	0.0	**14.0**
Storage containers							
Plastic bottle or containers	13.1	16.1	12.4	14.6	12.8	6.2	**75.2**
Glass bottles	0.4	5.5	11.4	6.6	7.0	5.9	**36.8**
Clay pots	9.2	2.9	1.8	6.6	0.0	2.2	**22.7**
Metallic saucepans	0.4	3.6	0.4	2.2	0.4	0.0	**6.9**
Polythene bags	0.0	0.7	0.0	4.7	0.4	0.0	**5.8**
Tins	1.8	0.0	0.7	1.8	0.0	1.5	**5.8**
Storage area							
House floor & hanging in the house	16.8	17.2	13.1	12.4	12.4	6.2	**78.1**
Granary floor	0.0	1.1	2.2	9.9	0.4	2.9	**16.4**
Kitchen floor and hanging in kitchen	1.5	0.7	0.4	4.4	1.5	0.4	**8.8**
Shelf life of oil (Months)							
2-3	9.2	6.9	5.7	5.5	12.0	1.9	**41.2**
Less than 1	3.4	10.7	4.2	9.9	0.8	0.0	**29.0**
More than 4	3.8	3.1	2.7	2.5	0.9	2.3	**15.3**
Uses of shea oil							
Food sauce	8.0	14.2	9.1	11.7	9.9	4.7	**57.7**
Selling for income	10.9	13.1	2.2	12.8	8.8	4.4	**52.2**
Cosmetic for smearing	5.5	14.2	12.4	9.5	1.5	1.8	**44.9**
Frying foods	6.9	5.1	7.7	11.3	6.2	0.0	**37.2**
Baking	0.4	5.1	1.1	1.8	3.6	0.0	**12.0**
Lubricant	0.0	2.6	5.8	0.0	0.4	0.0	**8.8**
Traditional medicine (human)	2.6	0.0	0.4	1.8	2.2	0.0	**6.9**
Soap making	0.0	5.1	1.5	0.0	0.0	0.0	**6.6**
Cultural taboo functions	0.7	0.7	4.0	0.0	0.4	0.0	**5.8**
Traditional medicine (animals)	0.0	0.0	1.8	0.0	0.7	0.0	**2.6**
Poison Antidote	0.0	0.0	0.0	0.7	1.1	0.0	**1.8**
Shea cake							
Local salt (ash)	10.2	4.4	0.4	5.5	3.6	1.8	**25.9**
Mosquito repellant	6.6	3.6	1.1	0.0	8.4	0.0	**19.7**
Vanish/polish wood	0.7	3.6	12.4	2.2	0.4	0.0	**19.3**
Manure/fertilizer	0.0	7.7	1.5	3.6	0.0	0.0	**12.8**
Preserving wood	0.4	2.6	5.1	0.0	0.0	1.1	**9.1**
Smearing house floors	0.7	1.8	4.0	0.4	0.4	0.7	**8.0**
Lubricant	0.0	2.9	2.2	0.4	0.0	0.0	**5.5**
Mosquito larvicide	0.0	0.0	1.1	2.6	0.7	0.0	**4.4**
Traditional medicine	0.0	0.0	1.8	1.5	0.0	0.0	**3.3**
Fuel	0.0	1.1	0.0	0.4	1.1	0.0	**2.6**
Animal feed	0.4	0.4	0.7	0.4	0.4	0.0	**2.2**
Calabash cleaner	0.0	0.0	1.1	0.0	0.0	0.0	**1.1**

4.3 Proximate and mineral composition of shea fruit pulp in Uganda

4.3.1 Proximate composition

The proximate analyses of *V. paradoxa* fruit pulp are presented in Table 8. The fresh pulp contained vitamin C content that ranged from 85.59-124.86mg/100g while the moisture content ranged from 24.66 to27.57%. The dry pulp had total carbohydrate, crude fibre, total ash, crude protein, crude fat contents with values ranging from 61.13 to 64.25%, 10 to15%, 3.61 to5.9%, 3.09% to 4.15%, 1.5% to 3.5% , respectively. The energy yield ranged from 248.17 to 256.21kcal/100g.

Table 8: Proximate analysis for shea fruit pulp in the shea districts of Uganda

	District			
Parameter (based on dry basis)	**Lira**	**Katakwi**	**Pader**	**Arua**
Moisture content (g/100g) FP	27.57±0.13	25.97±0.42	24.66±1.22	25.79±0.97
Ash content (g/100g) DM	3.61±0.16	5.90±1.90	5.54±0.18	4.64±0.29
Crude oil (lipid) content (g/100g)DM	1.50±0.71	2.00±1.41	3.50±0.50	2.50±0.71
Crude fibre content (g/100g)DM	14.47±1.74	14.39±1.18	10.05±0.05	14.55±0.60
Crude Protein (g/100g)DM	3.09±0.12	4.15±0.33	3.18±0.11	3.74±0.06
Total carbohydrates (g/100g)DM	64.25±0.88	61.99±3.22	61.13±2.00	63.35±1.45
Calorie value (kcal/100g)DM	249.47	248.17	255.29	256.21
Vitamin C (mg/100gm)DM	111.86±20.55	124.86±0.82	109.90±1.06	85.59±5.49

DM- Dry Matter, FP- fresh pulp. Results in Table: 8 are means of triplicate determinations

There were significant variations in some of the proximate values of shea fruit pulp from one region to another (P≤ 0.05) (Table 9).

Table 9: Analysis of variance for proximate values for shea fruit pulp in shea zones of Uganda at (P≤ 0.05)

	P- values					
Parameter	**LK**	**LP**	**LA**	**KP**	**KA**	**PA**
Crude oil (lipid) content	0.698 [a]	0.106 [a]	0.293 [a]	0.317 [a]	0.698 [a]	0.292 [a]
Crude fibre content	0.959 [a]	0.070 [a]	0.959 [a]	0.035 [b]	0.880 [a]	0.009 [b]
Crude Protein	0.049 [b]	0.565 [a]	0.030 [b]	0.062 [a]	0.208 [a]	0.055 [a]
Total carbohydrates	0.439[a]	0.647a	0.531 [a]	0.743 [a]	0.64 [a]	0.931 [a]
Vitamin C	0.098 [a]	0.571 [a]	0.108 [a]	0.0 [b]	0.00 [b]	0.00 [b]

LK- Lira and Katakwi, LP- Lira and Pader, LA – Lira and Arua, KP- Katakwi and Pader, KA- Katakwi and Arua, PA- Pader and Arua.

[a] No significance difference (P≤ 0.05), [b] Significant differences (P≤ 0.05)

4.3.2 Mineral composition

The most predominant mineral found in the shea fruit pulp was calcium with values going up to 95.58mg/100g. Potassium and magnesium were also high with values of 52.0 mg/100g and 24.2mg/100g respectively. Sodium and iron minerals were generally low in the shea fruit pulps with values of 18.12mg/100g and 3.76mg/100g respectively. The highest value of calcium and magnesium were found in Katakwi district while the lowest was exhibited by samples from Arua district. Sodium was also highest in the samples from Katakwi district while the lowest was for samples from Arua district. Potassium was highest in the samples from Pader district and the lowest was in those from Lira district. Magnesium was highest in the shea pulp samples from Pader district but the lowest in those samples from Lira district. Although iron was very low in concentration, the highest value came from the Pader and Arua districts samples (Table 10).

Table10: Mineral composition of shea fruit pulp in shea districts of Uganda

	District			
Mineral (mg/100g)	**Lira**	**Katakwi**	**Pader**	**Arua**
Sodium	8.94±0.12	18.12±0.20	8.98±0.18	7.07±0.33
Potassium	47.89±0.23	52.03±0.32	63.55±0.27	42.04±0.28
Calcium	69.37±0.11	79.03±0.24	95.58±0.17	35.18±0.27
Magnesium	18.14±0.29	23.83±0.17	24.21±0.31	21.00±0.48
Iron	3.67±0.13	3.41±0.06	3.76±0.10	3.76±0.09
Na/K ratio	0.19	0.35	0.14	0.17

Analysis was done in triplicate

4.4 Physico-chemical characteristics of shea butter (*Vitellaria paradoxa*) oil from the shea districts of Uganda

4.4.1 Physico-chemical composition shea oil

The oil from the shea kernels in the different shea growing districts (shea zones) ranged between 41 and 53.56%. The shea samples from Katakwi district in Teso sub region exhibited the highest oil yield (53.56%) compared to the other districts of Pader, Lira and Arua. Analysis of the physical characteristic of shea oil various samples showed that there was a significant variation in colour but not refractive index and viscosity ($P \leq 0.05$). The colour ranged from orange to orange –yellow, refractive index was between 1.67-1.69 while viscosity was in the range of 2.4 to 2.8(Table 11).

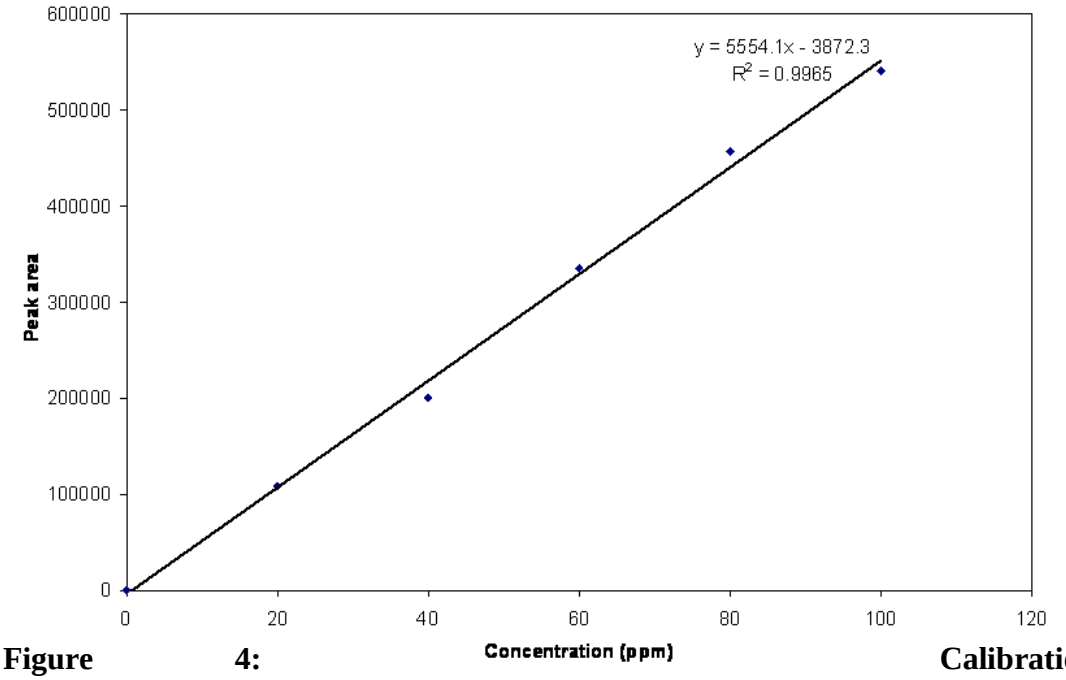

Figure 4: Calibration curve for vitamin E (α - tocopherols)

The colours of oil from Katakwi, Lira and Arua samples were yellow -orange while the Pader sample was orange. The Arua and Lira shea oil colour was more yellow-orange than that for Katakwi. The chemical characteristics of shea oil acid, peroxide, saponification and iodine values ranged between 2.3 and 12.59mgKOH/kg, 2.10 and

2.50meq/kg, 160 and 184mgKOH/g and 39.21 and 41.37 I_2g/100, respectively (Table 11).

Table 11: The physico-chemical properties of shea butter oil from the districts of Uganda

Physico-chemical properties	District				
	Pader	**Lira**	**Katakwi**	**Arua**	**Soya bean (*Gylcine max)* Oil [39, 40]**
Colour (Degree of colour mixtures)	Orange	Yel-Or	Yel-Or	Yel-Or	Brown
Refractive index	1.467 ± 0.001	1.468 ± 0.001	1.468 ± 0.000	1.469 ± 0.001	1.467
Viscosity (cP)	2.4 ± 0.2	2.6 ±0.2	2.8 ± 0.4	2.6 ±0.2	-
Oil yield content (%)	41.11±1.02	50.83±1.26	53.56±1.26	45.11±0.19	20.1
Acid value (mgKOH/kg)	3.00±0.53	3.18±0.27	2.30±0.66	12.59±0.17	1.0
Peroxide value (mEq/kg)	2.25±0.35	2.20±0.42	2.10±0.14	2.50±0.71	0.2
Saponification value (mgKOH/g)	177.32±1.89	192.15±1.99	160.35±1.21	184.14±1.85	193
Iodine value (I_2g/100g)	39.34±1.07	36.60±1.15	41.37±6.10	39.21±0.54	126
A-tocopherols content (mg/100g)	26.30±4.29	36.6±0.02	44.4± 0.29	40.0±0.17	-

The short abbreviations are represented as follows: Yel-Or ≡ Yellow-Orange colour, Yel-Gr ≡ Yellow-Green colour, Red-Or ≡ Red-Orange. All results in (Table 11) are means of triplicate determinations

The acid values of shea oil samples from Pader, Lira and Katakwi districts were significantly different from that of Arua district ($P \leq 0.05$). There was, however, no significant difference in peroxide, saponification and iodine values in the different shea districts of Uganda ($P \leq 0.05$). The α- tocopherol values in the shea districts of Uganda ranged between 26.3 and 44.0mg/100g. The values of α- tocopherol of shea oil samples from Arua was significantly lower than that of shea oil samples from Pader, Lira and Katakwi districts (Table 11).

4.4.2 Fatty acid profile of shea oil

The fatty acid composition of shea oil by district in Uganda is presented in Table12. The values of the five fatty acids in shea oil: palmitic, stearic, oleic, linoleic and arachidic fatty acids in Uganda ranged from 6.52 to 8.12%, 28.65 to 30.94%, 54.99 to 57.72%, 6.18 to 7.79% and 0.65 to 0.90%, respectively. Although there was no significant variation in the values of these fatty acids in the different shea districts of

Uganda ($P \leq 0.05$), oleic and stearic fatty acids were the predominant fatty acids in the shea oil of Uganda (Table 12).

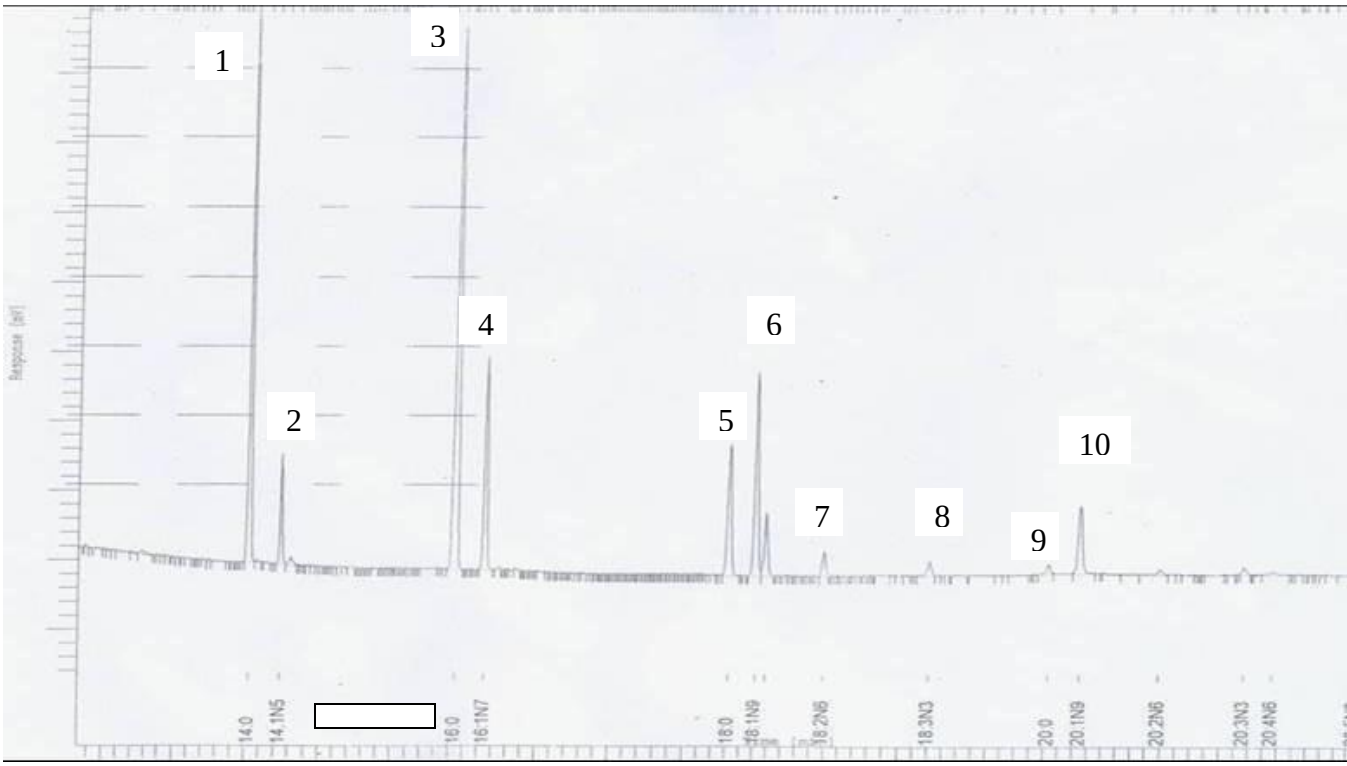

Figure 5: Standard chromatogram for mixture of standard fatty acid methyl esters. (1) Myristic acid; (2) Myristoleic acid ;(3) palmitic acid; (4) palmitoleic acid; (5)stearic acid; (6) oleic acid (7) linoleic acid (8) linolenic acid; (9) Arachidic acid; (10) Arachidonic acid (Experimental analysis, section 3.2.3 pg 25)

Table 12: The fatty acid profile of shea butter oil from the districts of Uganda.

Fatty acid properties	**District**			
	Pader	**Lira**	**Katakwi**	**Arua**
Palmitic cid ($C_{16:0}$)	8.04±1.23	6.52±0.18	7.14±.54	8.12±0.55
Stearic acid ($C_{18:0}$)	28.65±2.23	29.43±0.49	30.94±1.67	28.76±0.89
Oleic acid ($C_{18:1n9}$)	55.54±0.87	57.63±0.77	56.72±0.98	54.99±1.05
Linoleic acid ($C_{18:2n6}$)	6.86±0.44	6.42±0.12	6.18±0.11	7.79±0.92
Arachidic acid ($C_{20:00}$)	0.67±0.11	0.78±0.01	0.90±0.18	0.65±0.09

All results in Table 12 are means of triplicate determinations.

4.5 Variation in physico-chemical characteristics of shea oil extracted by different processing methods in lira district, northern Uganda

4.5.1 Physico-chemical characteristics

The results for colour, refractive index and viscosity of shea oil extracted by n-hexane solvent extraction, traditional boiling and cold pressing are presented in Table 13. The colour ranged from yellow-orange to red-orange. The colour exhibited by shea oil processed by cold pressing was red-orange while that exhibited by n-hexane solvent extraction and traditionally boiling methods were both yellow-orange respectively. The yellow orange colour was more in traditional boiling as compared to n-hexane solvent extraction. Although the refractive index ranged between 1.468-1.490, there was no significant difference in refractive index exhibited by the different extraction methods.

The viscosity values were in the range of 2.40-14.40cP and the values increased in the order of n-hexane solvent > cold pressing > traditional boiling. There was a significant difference in viscosity values ($P \leq 0.05$) exhibited by n-hexane extraction and the other two processing methods (Table 13).

Table 13: Selected physiochemical properties of shea extracted/ processed by three different methods

Physico-chemical properties	Shea oil extraction methods		
	n-hexane solvent extracted	*Traditionally boiled*	*Cold pressed*
Colour (Degree of colour mixtures)	Yelllow-Orange	Yellow-Orange	Red-Orange*
Refractive index	1.468±0.001	1.469±0.001	1.468±0.001
Viscosity (cP)	2.6±0.2*	14.4±2.1*	11.6±2.0
Acid value (mgKOH/kg)	3.18±0.27	3.59±0.46	6.92±0.45*
Peroxide value (mEq/kg)	2.2±0.42	5.05±1.91*	3.55±0.07
Saponification value (mgKOH/g)	192.15±1.99*	145.86±2.81	145.20±3.09
Iodine value (I_2g/100g)	36.6±1.15	38.84±0.36	38.73±1.00
A-tocopherols (mg/100g)	34.4±0.02*	45.5±0.91	34.4±0.31

*Results are means of triplicate determinations * Figures that are significantly different*

The acid value ranged between 3.18 and 6.92 mgKOH/kg and the values were highest for n-hexane solvent extraction followed by traditional boiling and cold pressing. While no significance variation in acid value ($P \leq 0.05$) between n-hexane solvent extraction and traditional boiling was witnessed, a significant variation in acid value was noticed between traditional boiling and cold pressing. The peroxide value ranged between 2.20 and 5.05mEq/Kg with the values in the order of n-hexane solvent extraction method greater than cold pressing method which was also greater than traditional boiling method. A significant variation ($P \leq 0.05$) in peroxide value was noticed in the three extraction methods (Table 13).

The saponification value was in the range of 145-192mgKOH/g with the values decreasing in the order of n-hexane solvent extraction less than traditional boiling method which was also less than cold pressing method. Although there was no significant variation ($P \leq 0.05$) in the saponification value exhibited by cold pressing and traditional boiling, the saponification value exhibited by n-hexane solvent extraction method was significantly different from one exhibited by both traditional boiling and cold pressing methods.

The iodine value exhibited by various processing methods fell in the range of 36.6-38.84I_2g/100g and the values increased in the order of n-hexane extraction, cold pressing, traditional boiling method, respectively. Comparison of iodine values exhibited by the different methods did not show any significant variation (Table 13). The α-tocopherol were between 34.4 and 45.5mg/100g. These values were highest for traditional boiling method followed by cold pressing and n-hexane extraction methods. A significant variation in α- tocopherol ($P \leq 0.05$) was observed between n-hexane solvent extraction method with traditional boiling and cold pressing methods (Table 13).

4.5.2 Fatty acid profile

The results of fatty acid profile of shea oil processed by n-hexane solvent extraction, traditional boiling and cold pressing are presented in Table 14. The different fatty acids identified in the shea oil sample extracted by the different methods were palmitic acid, stearic acid, oleic acid, linoleic acid and arachidic acid.

Palmitic acid value was between 6.12 and 7.00%, that of stearic acid, oleic acid, linoleic acid and arachidic acid had a range of 29.43 and30.66%, 55.06 and57.63%, 5.84 and 6.42 and 0.78 and 0.98%, respectively. There were no significant variation in the amounts of respective fatty acids ($P<0.05$). Palmitic acid was highest in traditional boiling method sample followed by n-hexane extracted and cold pressing methods, respectively (Table 14).

Table14: Fatty acid profile of shea extracted by three different methods

Fatty acid profile	**Shea oil extraction method**		
	n-hexane solvent extracted	***Traditionally boiled***	***Cold pressed***
Palmitic acid (16:0)	6.52±0.18	7.00±0.10	6.12±0.43
Stearic acid (18: 0)	29.43±0.49	30.06±0.41	30.66±0.53
Oleic acid (18:1n9)	57.63±0.77	57.01±0.64	55.06±0.36
Linoleic acid (18:2n6)	6.42±0.12	6.09±0.21	5.86±0.02
Arachidic acid (20:0)	0.78±0.01	0.98±0.23	0.83±0.08

Results are means for triplicate determinations

.

Stearic acid was highest in the samples extracted by cold pressing method followed by traditional boiling and n-hexane solvent methods, respectively. Oleic acid was highest for n-hexane followed by traditional boiling and cold pressing while linoleic acid was highest for n-hexane solvent extraction, followed by traditional boiling and cold pressing methods. Generally there was an increase in the percentage of saturated fatty acids (palmitic and stearic acids) in the traditional boiling method when compared to those samples of n-hexane solvent extraction method. The un-saturated fatty acid (oleic acid and linoleic acid) were higher for the samples of n-hexane solvent extraction method than that for traditional boiling and cold pressing methods (Table 14).

CHAPTER FIVE

DISCUSSION

5.1 Ethno-nomenclature of the shea tree (*Vitellaria paradoxa*) and its products in the shea zones of uganda

Given that shea tree and its products are very important in the livelihood of the rural poor, an understanding of the ethno-knowledge about shea tree and its products is important for continued use and conservation of the tree. The findings presented in this study therefore, clearly indicates that ethno-naming of the shea tree and its products varied widely among the studied ethnic communities in the shea zones of Uganda. Sometime during the previous century it became unfashionable to use vernacular names of plants. This happened (and still does) in the scientific fields of plant ecology and botany. The rationale for this seemingly 'reverse-xenophobic' decision is that local people name and classifies plants differently from ecologists/botanists (Hashim, 2007). Even then, it is still widely believed that vernacular names of plants could productively inform research on the conceptual categories of plants and their classifications.

The variation in the ethno-names reported in this study could also be due to the differences in languages spoken by these ethnic groups or dialectical differences in an ethnic group. For instance, the Acholi, Lango and Alur people speak the Western Nilotic languages which are found in the sub-sub phylum of Luo, closely related to the language of the Luo society in Kenya while Iteso speak the Eastern Nilotic language called the Ateso (Byrnes, 1992; Nyeko, 1996). The Lugbara and Madi, however, speak the Central Sudanic languages (ITA, 2008). Many vernacular names used for shea tree has previously been reported as a reflection of its extensive range of occurrence– nearly 5,000 km from Senegal (west) to Uganda (east) across the African Continent (Shea butter, 2008). The historio-nomenclature and synonymy of this tree is said to have followed a very tortuous evolution since the oldest specimen was first collected by Mungo Park on May 26, 1797 (Shea butter, 2008).

The few similarities in ethno-names of the shea tree (*Vitellaria paradoxa*) and its products in the shea parkland areas especially among the Luo speakers, and those

among Lugbara and Madi ethnic groups could perhaps be attributed to the shared historical background, movement of these people, intermarriages or trade among them (Nzita and Niwampa, 1998). The Luo migration for instance, brought changes during the 15th century. The Lango got mixed with the Acholi people and subsequent intermarriage resulted in the Lango losing their Ateker language and later migrating closer to Lake Kyoga in the 18th century after living for more than two hundred years in the Acholi region (Nzita and Niwampa, 1998). They lost the system of pastoralism and started farming and began to speak Luo.

The Luo migration also had influence on ethnic groups that already settled in the West Nile, northern and eastern regions of Uganda. They introduced their language and culture (Nzita and Niwampa, 1998). Therefore, these ethnic movements, intermarriages and modification of tribal languages could greatly account for the similarities in the ethno-names of the shea tree and it products. However, there is still a big gap in our knowledge and understanding especially to the meaning of the various ethno-names of shea tree and/or its products among the different ethnic groups as these were not sought in the study.

Based on the findings, it can be concluded that there was a wide inter and intra variability in ethno-names of the shea tree and its products among ethnic groups living in the shea parklands of Uganda. For instance, Alur ethnic group call the shea tree as *yao, yen, danyu or awa* while they call the shea nut as *pok yao, apoka yao, awakorongo, den yao nyige or pok sundri*. These varieties of ethno-names are perhaps a reflection of the extensive range of occurrence of the shea trees including ethnic moments, intermarriages and modification of tribal languages. There is need also to investigate whether the meaning of various ethno-nomenclatures are in anywhere linked to prototypes or conservation issues that can be used to enhance conservation of shea trees in Uganda or beyond.

5.2 Post harvest indigenous knowledge and practices of shea butter products in the shea zones of Uganda

5.2.1 Shea fruit collection

The post harvest handling practice of shea butter in Uganda begins with the fruit collection which is mainly done in the rainy season in the months between April and June. Although the rain at this time facilitates the falling down of the ripe fruits, it tends to speed fermentation of the fruit pulp and germination of the shea nuts. According to Maranz *et. al*., (2004), fermentation increases the heat in the shea nuts which in turn increases free fatty acids in the shea oil obtained from the shea kernels. Since shea fruit nuts are recalcitrant and can germinates within 3-4 days (PROTA, 2007), the germination of shea nuts also has been reported to increase free fatty acid in the shea butter oil with direct influence on its quality. To avoid processing of shea oil of poor quality, germinated seeds must be discarded (Lovett and Haq, 2000). Since the shea butter obtained can show variability in quality and may end up fetching low prices or even affecting its nutritional value (Ferris et al., 2001; USAID, 2004), the community needs to be sensitized and trained on best ways to carry out collection of shea fruits and other post harvest handling processes.

In Uganda most of the respondents collect shea fruits on the ground. This has been attributed to difficulty in separating ripened and fully mature fruits (PROTA, 2007). As maturity of fruits with seed oil has been reported to influence oil yield (Gesch *et al.*, 2005), it could be the reason why only fallen ripen shea fruits are harvested and any unripe, fermented and immature fruits are sorted out. With increasing demand for shea butter both locally and internationally, harvesting of shea fruits from the tree may be predicted thus a need to investigate the shea kernel oil yield content and variability in shea oil quality with maturity in Uganda.

The collection of the shea fruits in Uganda is mainly a woman's activity carried out both in the mornings and afternoons. This could be because most of the shea tree areas in the farms and fruits are collected after gardening. The collected fruits are depulped by mainly eating because the fruit pulp is a a delicacy among shea parkland communities (Maranz and Wiesman, 2004). Although the shea fruits

are mainly collected from under the shea trees (having fallen down under their own weights), wind or rain, shaking from the parent shea tree and collecting the shea fruits under other non shea trees in the neighborhood have been reported in the area. According to FAO and CFC (2005), shaking may cause both ripe and unripe fruits to fall while the shea fruit usually found under non shea trees would be transported by birds, bats or monkeys for their own consumption. At home, the shea fruits are subjected to sorting that mainly removes rotten fruits. The good fruits are then cleaned with water to remove the sand. Besides, the cleansed fruits pulp being eaten and always enjoyed by all the family members in the shea parklands, they are also sold for cash income. Since the storage period for shea fruits is short (2days), the pulp can be dried into powder for future use as shea cake. Both local government and researchers should therefore advocate for proper drying of shea fruit pulp.

5.2.3 Shea kernel drying and storage

Issues of variability in quality of shea butter oil due to post harvest handling practices such as drying and storage have been raised by Lovett and Haq (2000) and Maranz *et al.*, (2004). The high moisture content of the shea kernel due to poor drying conditions and storage has been reported to increase the free fatty acids of the shea oil resulting into poor quality (USAID, 2004). In this study, majority of the respondents reported that shea nuts and kernel are directly sundried (Table 6) as opposed to West African countries where the fruits or nuts are first parboiled. According to FAO and CFC (2005), parboiling is a process meant to deactivate enzymes responsible for formation of free fatty acid before sun drying.

Although in Uganda shea nuts and shea kernels are directly sun dried without parboiling, the shea butter from Uganda has not been reported with high free fatty acids compared to W. African shea butter. For example, Adikini (2002) reported acid value of shea butter of shea kernels purchased from local market in Uganda to be 8mgKOH/kg. This value is within the proposed standards for African shea butter (UNBS, 2004). What this means is that sun drying post harvest practice for shea butter in Uganda could be promoted even beyond since parboiling may increase the costs and time for production of shea butter. Where possible, it might even be

necessary to use properly made or designed solar driers including drying on clean cemented floors.

Drying of shea nuts under shade reported in the area may delay loss of moisture content in the shea kernel. This is because the harvesting of shea fruits takes place during the rainy season and there is over burdening of women to carry them in and out of the sun as women are also involved in other domestic activities. During sun drying, the nuts are prevented from getting in contact with water to avoid contamination of nuts with fungus which is carcinogenic. According to CFC and FAO (2002), moisture content of 10-12 % maximum has been recommended for shea kernel before storage in order to increase the shelf life. However, the low rate of moisture loss during drying under shade may increase the free fatty acids in shea butter since enzymes responsible for free fatty acid may remain active for some time.

Even if drying of shea kernel under shade in Uganda may increase free fatty acids in shea butter, no studies on the variation of free fatty acids for shea nuts dried under and outside shade have been reported. A study designed to investigate physico-chemical characteristics of shea butter dried under shade therefore becomes imperative now that the demand for shea butter products has tremendously increased (Ferris et al., 2001).

Once the nuts were dried, de-husking was mainly done by use of stone. This is because there are no appropriate technologies for dehusking in rural areas. The dry kernels are mainly placed in sacks and stored on floors in houses. The storage sacks are easily available in rural areas for storage of agricultural harvest. To maintain the kernel dry through out the storage period, it is regularly brought out in the sun for re-drying (FAO and CFC, 2005). This is expected to ensure that the quality of shea butter oil processed at any time would be consistent.

5.2.4 Shea butter extraction

Although 82% of the respondents were involved in shea butter extraction in the study area , shea butter has been reported to be extracted by traditional boiling for decades. The indigenous traditional process has been reported to be that is labour intensive and a cause for variability in shea butter quality due to post harvest handling

practices (FAO and CFC, 2005). Although post harvest practices process such as roasting, boiling and storage may increase oxidative parameters of shea butter as have been reported by PROTA (2007) and Kapseu *et al.,* (2007). So far no particular studies on physico-chemical characteristics of traditionally boiled extracted shea butter have been reported in Uganda. It is because of these that such a study for assessing the physico- chemical characteristics of indigenous traditional processed shea oil is required..

Traditionally boiled extracted shea butter has continued to be sold in local markets in Uganda with the quality being determined by only the physical parameters such as colour, taste and hand fill of the shea butter. The best colour for quality shea oil reported by 50% of respondents is brown colour (Table 7). Although the Uganda National Bureau of Standards has set draft standards for traditionally boiled extracted shea butter, there is need to investigate the physico-chemical parameters of shea butter processed traditionally by the community so that appropriate quality control parameters can be set. Traditional shea butter extraction has been considered to be a labour intensive activity producing low yield of 30% or less as reported by over 60% of the respondents (Table 7).

According to FAO and CFC (2005), the traditional extraction process also demands a lot of resources for production. In this study the respondent reported that to produce half a litre of shea butter in Uganda, it would require a minimum of 2 hours from shea kernel preparation depending on experience of the processor. Although this is considered too much a time, in West Africa the same output has been reported to take up to 24 hours (FAO & CFC, 2005). This suggests that it could be easier to process the Uganda shea butter than that of the West Africa.

Even if development of improved technology for extraction of shea butter has been going on for decades in Africa, the mechanical manual pressing method so far tested has been found to be more efficient than traditional boiling extraction method which gives the shea kernel oil yield of between 30 and 35%. This is low as compared to the solvent extraction method which gives over 50% of the oil from Uganda shea kernel (Maranz *et al.,* 2004). Besides having low yield output , the mechanical pressing method for shea butter may even press out non nutritional

materials in shea kernels such as tannins into the shea butter. As the demand for shea butter increases,, shea butter extraction process should however not exclude making a modification of the traditional boiling method since a majority of shea processors are already used to it. The post harvest indigenous knowledge and practices indicate that some practices such as harvesting and drying need to be emphasized in ensuring quality of shea butter. Training of the farmers on harvesting techniques, introduction of solar drier for shea kernel drying and modification of traditional boiling process of shea butter is appropriate for consistency in quality and yields of shea butter. Investigation on the influence of post harvest handling practices on quality of shea butter needs to be carried out for appropriate quality control of traditionally extracted shea butter in Uganda.

5.3 Proximate and mineral composition of shea fruit pulp in Uganda

Proximate composition

The proximate composition exhibited by shea pulp samples in this study indicate that vitamin C content of shea fruit pulp ranges from 86-125mg/100g in the different shea zones of Uganda. In comparison to vitamin C content of other common fruits such as oranges (41mg/100g), lemon (41mg/100g), pawpaw(69mg/100g) and mango (28mg/100g) (Nji and Onajobi, 2002), the vitamin C content in shea fruits is high, although lower than value of 196mg/100g reported for shea fruits in Ghana (CRIG ,2002). This variation could be attributed to environmental condition and post harvest handling (Wilhelmina, 2004). Although the values of vitamin C were high, it was also noted that there was a significant variation ($P<0.05$) in different shea zones of Uganda (Table 9). The variation of vitamin C content in different shea zones could also be due to environment factors (Wilhelmina, 2004) and the ability of the shea fruit to synthesize vitamin C (Vara *et al.,* 2001; Naidu, 2003; Laing and Bulley, 2007).

Even if un-ripe fruits normally contained high vitamin C (Nji and Onajobi, 2002), the ripe shea fruits in this case is even richer in vitamin C making it a very important nutrient in the shea fruit pulp at the time of shea fruit consumption. Vitamin C is one of the essential nutrients needed by the human body. It is a good antioxidant (Cheman *et al.,* 1999); it lowers blood pressure and enhances immunity (FAO, 2007). It is anti-carcinogenic and also prevents colds (Akhilender, 2003). According to recommended daily allowance (RDA) for vitamin c, 100-120mg per day is good for adults and lack of it causes scurvy (Akhilender, 2003). Regular consumption of shea fruits therefore can raise the nutritional profile and health status of the population of the shea fruit community especially at this time when there are food shortages in the world and rampant emerging diseases.

The values of total carbohydrate contents in shea fruit pulp in the different sub regions ranged from 61-64% (Table 8). According to Pearson (1990), values of total carbohydrates in the range of 40-60% are for both edible domesticated and wild fruits. Different carbohydrates such as glucose, fructose and galactose has been

reported in the shea fruit pulp (Neuwinger, 1994). In this study, the results of the carbohydrate content across the different sub regions of Uganda did not show any significant variation ($P \leq 0.05$) (Table 9). This shows that carbohydrate content remains almost constant through the shea belt in Uganda. Carbohydrates are very vital in nutrition because they are good sources of energy (Anhwange *et al.*, 2004). According to Okullo *et al.*, (2004) the shea fruits harvesting season coincides with a season when a lot of energy for agricultural planting is needed. Therefore, consumption of the shea fruit pulp after hard labour provides an immediate source of energy for the farmers. This therefore justify the promoting of consumption and commercialization of shea fruits in the shea zones of Uganda and beyond.

The crude fibre content is beneficial in diet of man because it plays an important role in decreasing many disorders such as constipation, diabetes, cardiovascular diseases and obesity (Ramulu and Rao, 2003; Chau and Yaung, 2003; Yusuf *et al.*, 2007). The value of crude fibre content for shea fruit pulp was 10.0-15.0%. These values are within the crude fibre of most wild and domesticated fruits (Pearson, 1990; Ramulu and Rao, 2003). In Uganda, the samples from different shea zones showed a significant variation in crude fibre content. The crude protein content obtained in this study was between 3.0-4.0% and there was no significance variation across the different shea zones in Uganda (Table 8). According to Marakog lu, *et al*., (2005) most edible fruits fall within this range. The crude protein content values in the shea fruit pulp obtained in this study in different shea zones of Uganda is not different from the finding of Maranz *et al.* 2004 but is lower than that of West African shea fruit pulp (Prokarite, 2008). Variation in crude protein is normally associated with differences in environmental conditions (Maranz *et al.*, 2004).

Since the values are not significant, the protein content remains constant through out the shea zones of Uganda. This is quite important because proteins play a very important role in nutrition by catalyzing, regulating, protecting and providing energy (Hergaty, 1988). Protein deficiency causes growth retardation, muscles wasting, edema, *kwashiorkor* and collection of fluids in the body (Anhwange *et al.*, 2004). The shea fruit protein can supplement plant protein sources such as beans and

peas widely consumed in many rural homes. Therefore, encouraging consumption of shea fruits among rural communities can be a good protein supplement in the diet.

The crude oil (lipid) content of shea pulp ranges from 1.5-3.5%. These shea pulp crude oil values are comparable with crude lipid content of 2.0% for most wild fruits (Pearson; 1990; Marakog lu, *et al*., 2005). In this study, the crude lipid content of dry shea fruit pulp differs from the result of the fresh pulp (1%) reported by FAO (2007). The dry fruit pulps have higher values of crude lipids because of the low moisture in the sample.

Comparison of result across the different shea zones of Uganda shows a significant variation ($P \leq 0.05$) in the amounts of crude lipids (Table 9). This variation could be due to environmental conditions such as temperature and rainfall and genetic variations resulting from cross pollination. Lipids play a very important role in nutrition and health (Hegarty, 1988, Anhwange *et al.,* 2004; Agatemor *et al.,* 2006) as they are major sources of energy and anti oxidant. Although the pulp contains low crude lipid content, these lipids could supplement energy from other carbohydrates and also unsaturated fatty acids which are very essential in the human diet (Anhwange *et al.,* 2004).

5.3.2 Mineral composition

As presented in Table 10, the shea fruit pulp from the different shea districts in Uganda contains high concentrations of calcium, potassium and magnesium. A significant variation in concentration of these minerals is observed in the different sub regions ($P \leq 0.05$). Calcium, the most abundant mineral in shea pulp is highest in Pader district (90mg/100g) while potassium is high in Katakwi district (50mg/100g). Variation in the mineral composition could be attributed to the environmental factors such as soil and climatic conditions. A significant variation in mineral composition in the shea fruit pulp has also been reported in Mali and Burkina Faso by Maranz *et al.,* (2004).

The amount of calcium (68mg/100g) exhibited in this study is higher than that reported by PROTA (2007) for calcium (36mg/100g) but not for magnesium (26mg/100g) which has been reported to be higher than 21mg/100g (PROTA, 2007).

Iron (4mg/100g) obtained in this study is twice the amount reported by PROTA (2007). On the other hand, Maranz *et al.,* (2004) reported potassium amounts of 400mg/100g which is much higher than the finding of this study. This variation could be due to differences in analytical methods used and also prevailing environmental factors. In this study, however, iron is the least mineral found in the shea fruit pulp (Table 10).

Since mineral are important in the diet due tof various functions in the body such as building strong bones, transmitting nerve impulses, making hormones and regulating body fluids, consumption of shea fruit pulp is highly recommended. Calcium, for example, serves as cofactors for many physiologic and metabolic functions; bone formation, nervous system, hormonal secretions, activation of enzymes and blood coagulation (Agatemor & Ukhun, 2006). When compared with Recommended Daily Allowance (RDA) by United States National Recommended Council (1989), 100g of dry shea fruit pulp powder contributes 8.8% of required calcium per day.

Potassium on the other hand is very important in protein synthesis, water balance, normal functioning of the nervous and muscles and absorption of glucose and glycogen (Hegarty, 1988). Similarly, 100g of the shea fruit pulp provides 2% of required potassium per day. Magnesium assists enzymes involved in the synthesis and breakdown of carbohydrates, fats, proteins and synthesis of DNA and RNA. Since 100g of the shea fruit pulp can provide up to 6.0% of RDA for magnesium, 2.0% potassium and 8.8% calcium, respectively, eating of shea fruit pulp can supplement the available minerals required by the body.

According to Yusuf *et al.,* (2007), Na/K ratio is of significant importance in the control of high blood pressure where even a value of less than the value one is recommended for controlling high blood pressure. In this study, the Na/K ratio range was found to be 0.17-35. This Na/K ratio values make shea fruit pulp a valuable resource in the management of high blood pressure. As high blood pressure is one of the emerging non-communicable diseases in developing countries including Uganda, consumption of shea fruit would provide an alternative measure for controlling high blood pressure.

Given the proximate and the mineral composition values obtained in this study, it can be concluded that the shea fruit pulp proximate composition is rich in vitamin C, total carbohydrates and crude fibre. The investigations indicate that the Ugandan shea fruit pulp has adequate nutrients comparable to other edible fruits for the shea producing communities. Due to the nutritional value and reported health potential of shea a fruit pulp, shea fruit from Uganda should be promoted as nutritious fruits. Since variation in proximate and mineral composition in different districts of Uganda exist, there is need to investigate the cause of this variability

5.4 Physico-chemical characteristics of shea butter (*Vitellaria paradoxa*) oil from the shea districts of Uganda.

5.4.1 Physicochemical composition of shea oil

With emerging shea oil market in the world, oil yield or fat content is the most important characteristic to be considered. The oil yield from shea kernels in the different districts of Uganda varied from 41 to53%. The shea kernel oil content exhibited in the different shea districts of Uganda has also been reported by Di-Vincenzo *et al.,* (2005). Even then, the shea oil kernel content for Katakwi district of 53.56 % is distinct (Maranz *et al.,* 2004). The shea oil yield content of above 40 % obtained for the different districts of Uganda is good since the shea oil yield content ranging from 20% to 60% have been reported (Tano-Debra *et al.,* 1995; Boffa *et al.,* 1999; Maranz *et al.,* 2003; Maranz *et al.,* 2004, Di-Vincenzo et al.,2005; Kapseu *et al.,* 2007).

According to Di-Vincenzo *et al.,* (2005), Uganda's shea kernel oil content was the highest in Africa. The shea oil content for Pader, Lira and Arua districts were found to be relatively low compared to the oil content of samples from Katakwi district. The differences in the shea oil content could be attributed to environmental influence, genetic variation (Kapseu *et al.,* 2007), geographical location and other agronomic factors (Dei *et al;* 2007). Katakwi and Lira districts with the highest shea oil content (Table 11) are characterized by bi-modial rains which are usually experienced between April–August with hot and dry season occurring from November to February which is the fruiting season for shea trees (Okullo *et al.,* 2004).

The high shea oil content in Katakwi and Lira could be due to their early fruiting during the dry season between December and February where temperatures range between 31-35^{o}C (SDER, 1997). According to Maranz and Weisman, (2003), high elevation and cool temperatures are also associated with high levels of shea kernel oil content. In Uganda, different shea districts have elevation of between 1100-1350m. Katakwi and Lira shea districts areas with high shea oil content fall within elevations of between 900-1100m and with temperatures of between 30-35^{o}C during dry season. On the other hand, Pader and Arua districts with low shea oil

content have elevations of between 1200m and 1350m and experience temperatures ranging from 35-40^{o}C. The high oil content from Uganda makes it a good source of shea oil supply in the world.

In commercial setting such as manufacturing and trade, evaluation of physico-chemical characteristics of shea oil quality is very significant. The shea oil acid value obtained in this study is representative of samples from many trees. Because of recalcitrant nature of shea fruits, early germination may increase the free fatty acid of the shea oil (USAID, 2004). Although Maranz *et al.*,(2004) report that free fatty acid of shea oil range between 1 and 20% with highly variable peroxide values, the range of peroxide value obtained in this study of less than 10 is the characteristic of the majority of many edible vegetable oils (Dhellot *et al.,* 2006).

The saponification value of shea oil is lower than the reported saponification values for soya bean, peanut, cotton, sun flower and olive (Anhwange *et al.,* 2004; Dhellot *et al.,* 2006). The iodine value of shea oil exhibited in this study is also lower than other iodine values for most vegetable oils (Salam *et al.,* 2005). The peroxide value (2.1-2.5 mEq/kg), saponification value (160-192mgKOH/g) and iodine value (39-41I_2g/100g) are however similar to those reported previously (Adikini, 2002; Kapseu *et al.*, 2007). The colour of shea oil obtained in this study is also similar to those of Tano-Debrah and Yoshiyuki (1994) and Adikini (2002). The yellow-orange colour of shea oil samples may be an indication of the presence of ß-carotene pigments in shea oil which is nutritionally important (Adikini, 2002).

The viscosity values obtained for shea oil samples from shea districts of Uganda fall in the category of most fluids (Dhellot *et al.,* 2006) and also conform to the work of Adikini (2002). The refractive index also does not differ so much from refractive indices of sun flower, soya bean and palm oil (Zeb and Ahmad, 2004). Since the chemical composition of shea oil obtained conforms to the proposed regional standards for shea butter standards (RCT, 2006), shea oil can be commercialized both locally and internationally.

Although tocopherols represent an important class of anti oxidants and shea oil is rich in α-tocopherol (Maranz et al., 2004), moderate values of between 26.3mg/100g and 44mg/100g with significant variation ($P \leq 0.05$) has been exhibited

as compared to that of Maranz and Weisman (2004). Several factors linked to environment factors, storage period of the oil and genetic influence have been reported to cause variation in α-tocopherols (Maranz and Weisman 2004; Tchobo *et al.*, 2007). The low values of α- tocopherol obtained in this study for some regions could be due to over storage of shea oil samples before analysis. Maranz and Weisman (2004) reported an α- tocopherol mean value of 29 μg/g (mg/100g) for Uganda besides the mean value of 220μg/g for different countries in Africa. According to Maranz and Wiesman (2004) α- tocopherol always increase with temperature during seed maturation and also drought. The high α- tocopherol values (44mg/100g) obtained in Lira district compared to other shea districts in Uganda could be due to the high temperatures experienced in the area (Maranz and Weisman 2004)

Characterization of shea oil for nutritional, pharmaceuical and cosmetic purposes is therefore very important since changes in α- tocopherol can be an aspect for monitoring of the oil quality. Even if shea oil has been used as vegetable fat, cosmetic as well as medicine for centuries (USAID, 2004), the cosmetic industries, for example, require oils with unique fatty acid profile such as oil with very high oleic fatty acid (the Uganda shea oil) which makes a soft base for the cream (Maranz *et al.,* 2004). Acid value, peroxide value, saponifiaction value and iodine value are also indicators of edible oils that are suitable for food, cosmetic, soap making and lubricants. This is so because increase in these values can be associated to rancidity of oils due to oxidation. Thus, the changes in acid, peroxide and iodine values can be used in monitoring deterioration of shea butter.

In general, the chemical composition of shea oil indicates that it can be used as edible vegetable oil, cosmetic, lubricant and for soap making (Anhwange *et al.*, 2004). Anti oxidants such as α-tocopherol can be responsible for reducing degenerative diseases (Kornsteiner et al., 2005) and also for mopping up free radicals responsible for oxidative damage of the skin (Olukemi et al., 2005). Since α-tocopherol is one of the groups of fat soluble vitamin E compounds that can not be synthesized by animal cells, it must be obtained from plant sources (Durmaz and Gopkinar, 2006). According to Kornsteiner *et al.*, (2005) and Alander, (2004), α-

tocopherol are very important in nutrition, cosmetic and health. The presence of α-tocopherol in shea oil therefore makes it a very important oil in the human diet.

5.4.2 Fatty acid profile of shea oil

Although shea oil is characterized by 16 saturated and unsaturated fatty acids (Di-Vincenzo *et al.*, 2005), the five fatty acids (oleic , stearic, palmitic, linoleic and arachinidic) are the most dominant with values greater than 0.01%. The five fatty acid composition of shea oil in Pader, Lira, Katakwi and Arua districts of Uganda exhibited no significant variation ($P \leq 0.05$). Although Maranz *et al.*, (2004) reported that oleic fatty acid of shea oil from Uganda range between 37% and 55%, the differences in shea oil fatty acid reported in this study could probably be due to variation in the harvesting season, geographical locations (PROTA, 2007) and genetic variability (Maranz *et al.*, 2004).

Variation in fatty acid composition between Ugandan and West African shea oil has also been reported (Maranz *et al.*, 2004 and Di-Vincenzo et al., 2005). In these reports, Uganda's shea oil had 57% oleic and 30% stearic acid while the West African had 45% oleic and 34% stearic acid. Linoleic acid is an essential fatty acid that is very important in nutrition because of its unsaturation. Shea oil samples from the shea districts of Uganda had linoleic acid in the range of 6% to 8% which is lower than in passion fruit seeds with values of 67% to 74% (Nyanzi *et al.*, 2005) and sunflower oil with values of 48% to 74% (Maritza *et al.*, 2006). This linoleic acid value makes shea oil a moderate source of essential fatty acids in the human diet.

According to Dei *et al.*, (2007), the chemical composition and dietary profile of the fat is important in human nutrition since fats serves as a source of dietary energy. The high levels of un saturated fats in Uganda's shea oil makes it a better edible oil as it can improve digestability, easily infiltrate the bile salt and bind to low weight proteins (Dei *et al;* 2007). The higher values of oleic fatty acid in shea oil than in soya bean oil (25%) and palm oil (36%), makes shea oil a good source of un-saturated fats too (Dhellot et al., 2006; Dei et al;, 2007). The linoleic fatty acid (6-

7%) of shea oil from Uganda when compared with soya bean oil (6.1%) and palm oil (5.5%) make it a better source of essential fatty acids (Ajayi *et al.,* 2006).

Since un saturated fatty acids have been reported to prevent cardiovascular diseases (Kornsteiner *et al.,* 2005); which are now increasing in developing countries such as Uganda, especially among the urban population, shea oil could be a good alternative source for dietary fat especially at this time when food prices are increasing. The implication of this is that shea oil can be promoted both locally and internationally as very nutritious oil.

Because cocoa butter has high level of stearic and palmitic fatty acids just like shea oil, the shea butter has been recommended by European Union to be blended into chocolate as cocoa butter equivalent or improver which is more affordable substitute (Maranz *et al.,* 2004; Niel, 2008). The increase in the demand of shea butter in cocoa industry could lead to promotion and improvement in house hold income in the shea parklands. Since certification of shea kernels and shea butter is increasingly going to become important in the European markets (USAID, 2004), demand for consistency in quality of shea products exported to highly regulated markets would benefit from this study. Besides, information that has been generated through analysis of physico-chemical characteristic of shea oil could also be used to guide certification and traceability of shea products from Uganda.

Although results show that the different component (chemical composition and fatty acid profile) of shea oil from the different shea district in Uganda are not significantly different ($P \leq 0.05$) from each other, the differences in acid value, colour and α-tocopherols that are observed require further investigation associated with post harvest handling of shea oil. The characteristics exhibited by the physico-chemical composition and fatty acid profile of shea oil from Uganda make it a potential raw material for cosmetics (creams and lotions), soap, food processing (as edible vegetable oil) and in bakery/confectionery sector. These values are of high significance in the development of standards for Uganda's shea oil and for improving its commercialization and traceability is very important both locally and internationally.

5.5 Variation in physico-chemical characteristics of shea oil extracted by different processing methods in lira district, northern Uganda

5.5.1 Physico-chemical composition

Generally, the physico-chemical composition is an indication of the quality of oil and the valuable parameters include acid value, peroxide value and iodine value. In this study, comparison of the physico-chemical parameters of shea oil in n-hexane solvent extraction, traditional boiling and cold pressing methods showed that the acid value and peroxide value were relatively lower than those reported for other commercial and edible vegetable oils (Maritnez et al., 2008). Since these values are not significantly different, it indicates that extraction of shea butter by n-hexane solvent, traditional boiling and cold pressing methods does not affect the quality of shea oil.

Although there was a significant variation in both the acid value and peroxide value of shea oil extracted by the different methods, values exhibited in this study are within the range reported by Adikini (2002) and the proposed shea butter specification drafted by Uganda National Bureau of Standards (2004). The high acid value of between 4 and 7 and peroxide values of between 4 and 5 exhibited by cold pressing and traditional boiling methods compared to n-hexane of between 3 and 2 respectively could be due to either post harvest handling practices of shea oil or hydrolysis of triglycerides in the shea oil due to extraction processes. Post harvest practices such as harvesting; drying and storage have been reported to be related to increase of the fatty acid in shea oil (USAID, 2004; Kapseu *et al.,* 2007 and Choe & Min, 2007).

According to Kaul *et al.,* (2008), presence of peroxide has been reported to indicate increase in iodine value due to oxidative hydrolysis. In this study, peroxide value was found to increase with iodine value in the traditional boiling and cold pressing methods as compared to n- hexane solvent extraction method. Thus, the increase in peroxide value could be due to oxidative hydrolysis reaction during extraction processes. The boiling with water that is undertaken in traditional boiling and cold pressing of the oil could have caused oxidative hydrolysis leading to formation of peroxides. As reported by Maritnez *et al.,* (2008), water generally

favours hydrolysis of triglycerides in the oil. A high peroxide value, for example, could be responsible for the development of rancidity in the oil (Anhwange *et al.*, 2004). Since rancidity can affect the nutritional quality, physical appearance, flavor and safety of oil and is of great concern to consumers (Rathjen *et al.*, 1997), efforts should be made to minimize the development of rancidity in shea oil.

In addition to peroxides, increasing iodine value, it also increases the viscosity of shea oil extracted by traditional boiling and cold pressing methods. Since viscosity is a physical parameter that determines quality of vegetable oils, increase in viscosity is normally caused by oxidation and polymerisation of vegetable oil. In this study, the increase in the viscosity values exhibited in this study by traditional boiling (16cP) and cold pressing (11cP) methods as compared to n-hexane solvent extraction method (2cP) could be due to oxidation and polymerisation in the shea oil due to differences in extraction processes. Ways of minimizing variability in viscosity in shea oil extracted by cold pressing and traditional boiling methods need to be devised.

Colour on the other hand can be a good indicator of vegetable oil quality. The change in the colour of vegetable oil is mainly attributed to peroxidation, pigmentation or contamination (Lewis, 1990). In this study, the differing red–orange colour for cold pressing could probably be due to pigmentation in the oil as a result of the red colour from the kernel. The yellow-orange colour exhibited by the samples extracted by the traditional boiling and n-hexane solvent extraction methods could be due to either pigment or peroxidation. Although the samples extracted by n-hexane solvent extraction and traditional boiling methods exhibited similar yellow-orange colour, the level of differing for red was more in in the samples extracted by traditional boiling method. According to Maritnez *et al*, (2008), differences in colour could be due to either peroxidation or polymerisation of triglycerides in the shea oil. Further studies to investigate the causes of changes in the physical parameters of shea oil extracted by different methods would thus be required for monitoring the shea oil quality and promoting its commercialization.

Tocopherols in natural oils are very important nutrients required in the diet because of their anti oxidant properties. The results of this study indicate that shea oil

extracted by traditional boiling and cold pressing methods have high level of α-tocopherols than n-hexane solvent extraction method. According to Martinez *et al.*, (2008), the high temperature applied in traditional boiling and cold pressing could have reduced oxidation of α-tocopherols. Although values of α- tocopherol in shea oil produced by cold pressed (44.4mg/100g) and traditional boiling (45.5mg/100g) methods are high compared to n hexane solvent extraction method, these values are relatively lower than α-tocopherol value of 200mg/100g reported for shea oil sample (Maranz and Weisman , 2004). Even if this variation could be due location of the shea trees and the season of harvesting which were different, the different extraction methods may also have effect on the level of α-tocopherols in shea oil (Choe and Min, 2006).

5.5.2 Fatty acid profile

According to FAO and CFC (2005), the fatty acid profile is also important in determining the nutritional as well as physico-chemical characteristics of shea oil. The five major fatty acids, palmitic, stearic, oleic, linoleic and arachidic are all observed in the different methods and the values are all within values reported by Adikini (2002) and Maranz *et al.*, (2004). Since there was no significant variation in the fatty acid profile of shea oil extracted by different method, it signifies that the different extraction methods in this study do have the same effect on the amounts of the fatty acid profile.

Although, the n-hexane, traditional boiling and cold pressing shea oil extraction methods exhibited variations in the physico-chemical characteristics for some of the parameters measured, the values were within limits of edible oils. Even if the n-hexane solvent extraction, traditional boiling and cold pressing methods gave no significant changes in fatty acid profile, the increase in oxidative parameters in traditional boiling and cold pressing method as compared to n- hexane solvent extraction may demonstrate reduction in quality of shea oil. There is therefore a need to investigate cause of changes in physico-chemical characteristic of shea oil in different traditional boiling and cold pressing methods as well as their shelf life as a way of promoting commercialization of shea oil in Uganda and beyond.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

Based on the findings of this study, it can be concluded that:

a. There was a wide inter and intra variability in ethno-names of the shea tree and its products among ethnic groups living in the shea parklands of Uganda. These variations in the ethno-names of shea tree and its products are perhaps a reflection of the extensive range of occurrence of the shea trees including ethnic movements, intermarriages and modification of tribal languages.
b. The documented post harvest indigenous knowledge and practices indicate that some practices such as harvesting and drying need to be emphasized in ensuring quality of shea butter for local consumption and scaling its commercialization internationally.
c. The proximate and mineral composition values of shea fruit pulp showed that the Ugandan shea fruit pulp has adequate nutrients for both nutrition and health benefits hence its consumption needs to be promoted among communities in the shea producing zones. Shea fruit pulp Na/K ration of less than value one can indicate its potential in traditional medicine as an alternative treatment for managing high blood pressure.
d. The physico-chemical characteristics and fatty acid profiles exhibited by shea oil samples from the different shea zones of Uganda make it a possible raw material for use in cosmetics (creams and lotions), soap, food processing (as edible vegetable oil) and in bakery/confectionery sectors.
e. Although, the shea oil samples extracted by n-hexane, traditional boiling and cold pressing shea oil extraction methods exhibited variations in the physico-chemical characteristics, the values were within limits of other edible vegetable oils. Even if the shea oil samples extracted by n-hexane solvent extraction, traditional boiling and cold pressing methods did not show significant variations in fatty acid profile, the increase in oxidative parameters of the samples extracted

by traditional boiling and cold pressing methods as compared to n- hexane solvent extraction may demonstrate reduction in quality of shea oil.

9.2 Recommendations

The following recommendations have been made:

a. There is need to investigate whether the meaning of various ethno-nomenclatures of shea tree and its products are in anywhere linked to prototypes or conservation issues that can be used to enhance conservation of shea trees in Uganda or beyond.
b. Training of the farmers on harvesting techniques, introduction of solar dryers for shea kernel drying and modification of traditional boiling method of shea butter is appropriate for consistency in quality and yields of shea butter. Investigation on the influence of post harvest handling practices on quality of shea butter needs to be carried out for appropriate quality control of traditionally extracted shea butter in Uganda.
c. Since variations exists in proximate and mineral composition of shea fruit pulp in the different shea districts of Uganda, there is a need to investigate the causes of this variability.
d. The physico chemical and fatty acid profile of shea butter values obtained in this study are of high significance in the development of standards for Uganda's shea oil and enhancement of its commercialization and traceability both locally and internationally.
e. For promoting commercialsiation of Uganda shea oil, further investigate needs to be carried out on the the probable cause (s) of changes in physico-chemical characteristic of shea oil when extracted by either traditional boiling or cold pressing methods.
f. In order to make shea oil fetch better prices rather than selling of shea nuts/kernels (which may be sold at a low price), a thorough investitagition needs to be conducted on the shelf life of the shea oil extracted by various extraction methods.

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APPENDICES

QUESTIONNAIRE

APPENDIX I: QUESTIONNAIRE FOR ASSESSMENT OF POST HARVEST INDEGINEOUS KNOWLEDGE/PRACTICES AND USES OF SHEA BUTTER PRODUCTS IN UGANDA

Introduction

This questionnaire is aimed at assessing uses & the factors that affect nutritional quality of shea oil in relation to post harvest handling in Uganda. The questionnaire addresses three components in post harvesting management e.g. fruit harvesting, nut/oil processing & storage

Category of respondents

a) Farmer b) Farmer group/association

c) Commercial processor/trader ☐

Name of the farmer/ association/enterprise (optional)……

Age of farmer/ years of organisation existance……..

Gender. a) Female ----------b) Male----------

District……County……Sub county……

Parish ……..…Village……..

(A) Fruit Harvesting

1. What is the local name of the following in your local language

   shea tree ……Shea fruit…….

   Shea nut……Shea kernel…….Shea oil……..…..

2. Do you collect shea fruits?

   a) Yes (go to Qn.4) b) No (go to Qn.3 & proceed to Section B)

3. Who mainly collects the fruits?

   ……..

4. Who else in the family also collects shea fruits?

   ……..

5. In which months do you normally collect or harvest shea fruits?

   ……..

6. At what time of the day are the fruit mainly collected during harvesting?

   …….

7. Where are shea fruits collected from?……

8. Are there any difference between the shea trees in this area?

   a) Yes b) No

9. If yes, can you **briefly** describe their differences?

   ……
   ……

10. Is there any selection of the specific type of tree to collect from during fruit collection?

    a) Yes (go to Qn. 11) b) No (go to Qn.13)

11. If yes, what criterion is used to select the trees? Please give reasons for each criterion

Criteria	Description	Reason

12. Are the fruits picked only after they have fallen down from the tree?

a) Yes (go to Qn 14) b) No (go to Qn. 13)

13. If No, list other methods of shea fruit collection from the tree?

.....

14. Are the fruits sorted after collection? Yes …. No…..

15. If yes, where are the fruits sorted from? Please describe how they are sorted

……

16. How do you know that the fruit is ripe and ready?

.....

17. What are the uses of the fruits after collection from the tree?

……

18. How do you remove the pulp or flesh from the fruit?----------

19. How far is the place where you collect fruits from your home/work place?

……..

20. What type of container do you put and transport the fruits after collection?

……

21. Do you store fruits for sometime after collection?

a) Yes (go to Qn. 22.) b) No (go to Section B)

22. If yes, where do you store fruit after bringing home or to the processing point?

……

23. For how long can the fruits be stored after collection without getting spoilt?

……

(B) SHEA NUT DRYING & STORAGE

24. Do you process the fruit into nuts?

a)Yes (go to Qn.25) b) No (go to Section C-Qn32)

25. If yes, what method do you use to dry the seeds or nuts?

……..

26. What method do you use to open the seed kernel into nut?

……

27. After drying, where do you store or keep the nuts?

…….....

28. What is the longest period for nut storage before getting spoilt?

……

29. A part from oil , what are the other uses of the shea nuts?

……

30. Do you sell the shea nuts?

a) Yes (go to next Qn.31) b)No. (go to Section C-Qn 32)

31. If yes, could you explain in brief what happens from the time the nuts are dried to the point of sale……

(C) SHEA OIL PRODUCTION

32. Do you process shea oil?

a) Yes (go to Qn. 33) b) No (go to Qn.52)

33. Are the different nuts sorted before oil extraction?

a) Yes (go to 34) b) No (go Qn.35)

34. If yes, what are the differences in oils from different nuts? Please describe the differences

……

35. If No, is there any diffrence between oil processed by different persons?
Yes (go to Qn. 36) No (go to Qn.36)

……

36. Please could describe what is done to the stored nuts before oil extraction?

……..

……

37. Are there differences between oil processed from recently dried nuts and those that have been stored for some time? 1. Yes, 2.No. (go to 39)

38. If, yes, describe the differences.

……

39. For how long can the nuts be stored so that it remains in good condition for oil extraction?

.....

40. Could you list/briefly describe the processing steps involved in the shea oil processing from the nuts (**from nuts to oil**)?

……

40B: How long does it take you (hours) from roasting to final extraction of shea oil

……

41. How long (months or years) have you been processing shea oil?

……

42. Please describe your experiences in processing and storage of shea oil

.....

43. What are the different uses of the shea oil that has been processed?

……

44. How do you know that the oil processed is of good quality- in terms of?

Parameter	*Characterstics*
Colour	
Taste	
Smell/ odour	
Consistency	
Other	

45. What do you do to the oil cake /residue from shea oil processing?

……

46. Can you estimate the quantity of shea oil in approximately 1kg (2 cups) of the nuts?

.....

47. What type of container do you keep or package the oil after production?

……

..

48. Do you select the colour of the container for keeping or packaging the shea oil?
a) Yes (go to - 49) b) No (go to-50)

49. If yes, what is the colour(s) of the container?

……

50. If No, in your own view, what is the preferred colour of the container? Please give reasons

……

51. After processing, where do you keep or store shea oil?

……..

52. Do you sell shea oil?
a) Yes (go to Qn. 53) b) No (go to Qn. 54)

53. If the oil is for sale, how long can it stay in saleable form?

……

54. If shea oil is for home consumption, for how long can it stay before getting spoilt?

……

55. What normally tends to spoil the shea oil?

a) During processing (**describe briefly**)

……

……

b) After production/in storage? (**describe briefly**

……

……

56. Could you suggest ways by which processing of quality shea oil can be improved in this area?

……

57. Suggest ways by which the quality of shea oil can be maintained for home consmuption and sale?

……

……

58. Could you give (if any) other comments concerning the quality of shea nuts and oil?

……

……

THANK YOU FOR YOUR KIND COOPERATION

APPENDIX II: DESCRIPTION OF TRADITIONAL BOILING EXTRACTION METHOD OF SHEA BUTTER IN UGANDA

Traditional boiling method involves preparation of shea kernels, roasting, pounding, boiling and extraction of shea oill.

Preparation of dry shea kernels

The prepration process of shea kernels involves sorting out kernels that have fungal infection, broken pieces and abnormal small sizes.

Roasting of shea kernels

The roasting of shea kernels is done either in a saucepan or a pot containing ash, sand or gravel. Materials such as sand ash or gravel are used to prevent over roasting and create uniformity in the roasted shea kernels. After roasting, the colour of the kernel is supposed to turn black with its inside being red. The roasted nuts, thereafter, are then cleaned to remove ash, sand or gravel using leaves of some plants. Examples of these plant species include Sodom *apple, Combretum sp* and many others that are yet to identified botanically.

Preparation of shea kernel paste

The clean roasted shea kernels are pounded in a traditional wooden mortar to produce paste. The grinding of the paste is optional depending on the processors skills. Some of the processors prefer less fine pounded paste while some prefer paste more fine milled with a traditional grinding stone. Miling eases extraction of shea oil, thus, increasing the shea oil yield.

Extraction of shea oil

The roasted shea kernel paste is boiled in water using either a pot or saucepan. The boiling paste is continuous stirred until oil is separated and floats on top of water. The shea oil which is on top is either skimmed off or decanted into a container. Some shea oil processors, reboil the extracted butter to remove water residues. The extracted shea butter is then packaged in a container which is kept or stored in a house, akitchen or agranary.

APPENDIX II1: DESCRIPTION OF COLD PRESSING EXTRACTION METHOD FOR SHEA BUTTER IN UGANDA

The cold pressing method for shea butter involves preparation of shea kernels, crushing and pre heat treatment of shea kernels , pressing shea oil from shea kernel paste and boiling of pressed shea oil

Preparation of dry shea kernels

The prepration process of shea kernels involves sorting out kernels that have fungal infection, broken pieces and abnormal small sizes

Preparation of shea kernel paste

The dry shea kernels are crushed into paste with a motorized machine, preheated with hot water and there after packed in bags for pressing. The type of shea butter extraction hot water pre heated paste is "cold pressed shea butter" while that pre heated by roasting "hot pressed shea butter". The differences in cold pressed and hot pressed shea butter is in the smell properties. The cold pressed has less characteristic shea oil smell as compared to hot pressed.

Extraction of shea oil

This can be done manually or by a machine. The paste in bags is pressed to expel out the shea. The pressed shea butter is then boiled in water while being stirred continuously . While being boiled and stirred, shea oil floats on top which allows easy skimming off into a container. The skimmed oil is cooled and packaged in a containers..

APPENDIX IV: GC CHROMATOGRAMS FOR SHEA BUTTER EXTRACTED BY DIFFERENT METHODS

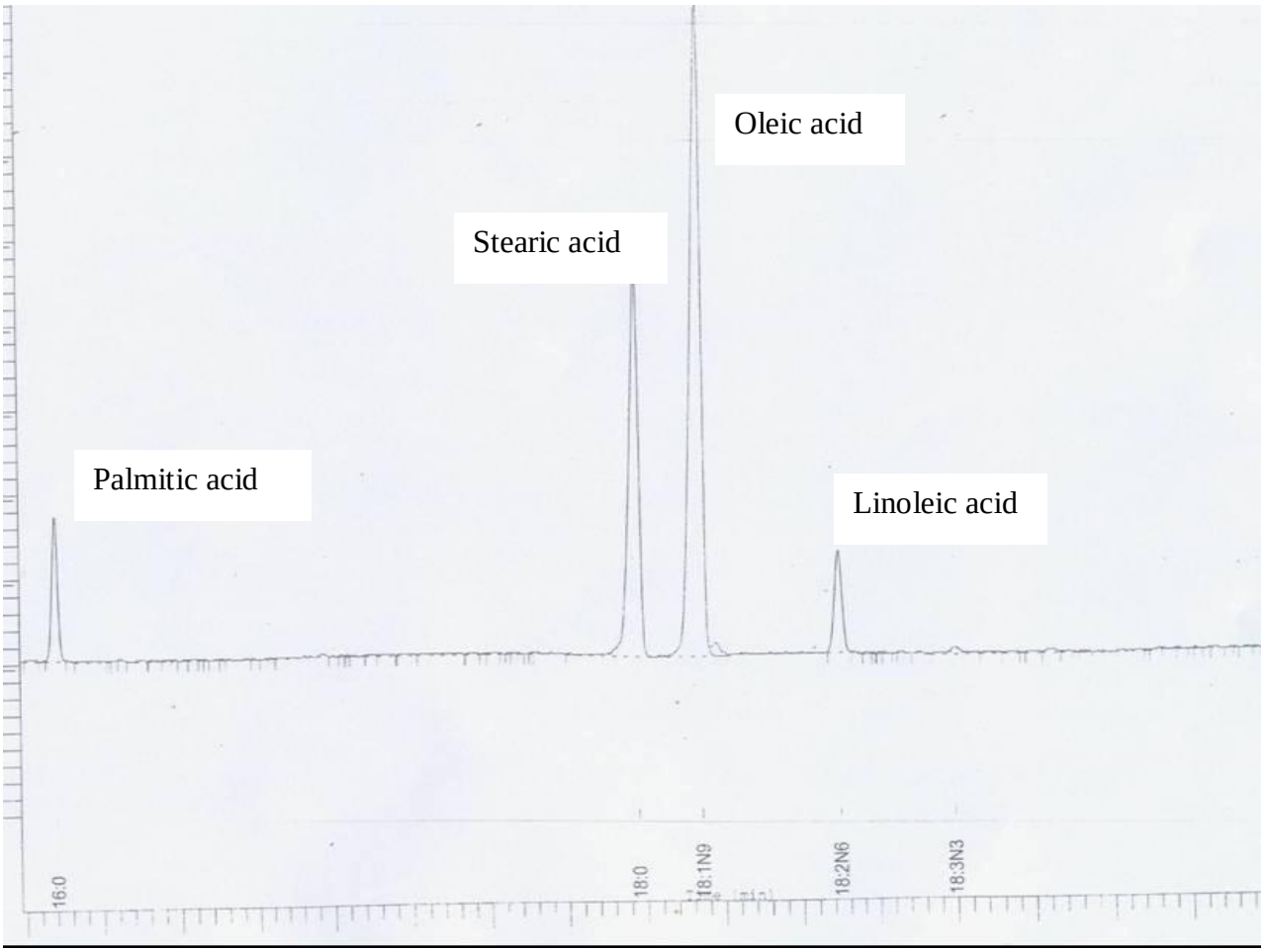

Figure IVa: GC Chromatogram for shea butter oil (FAME)extracted by *n*-hexane solvent

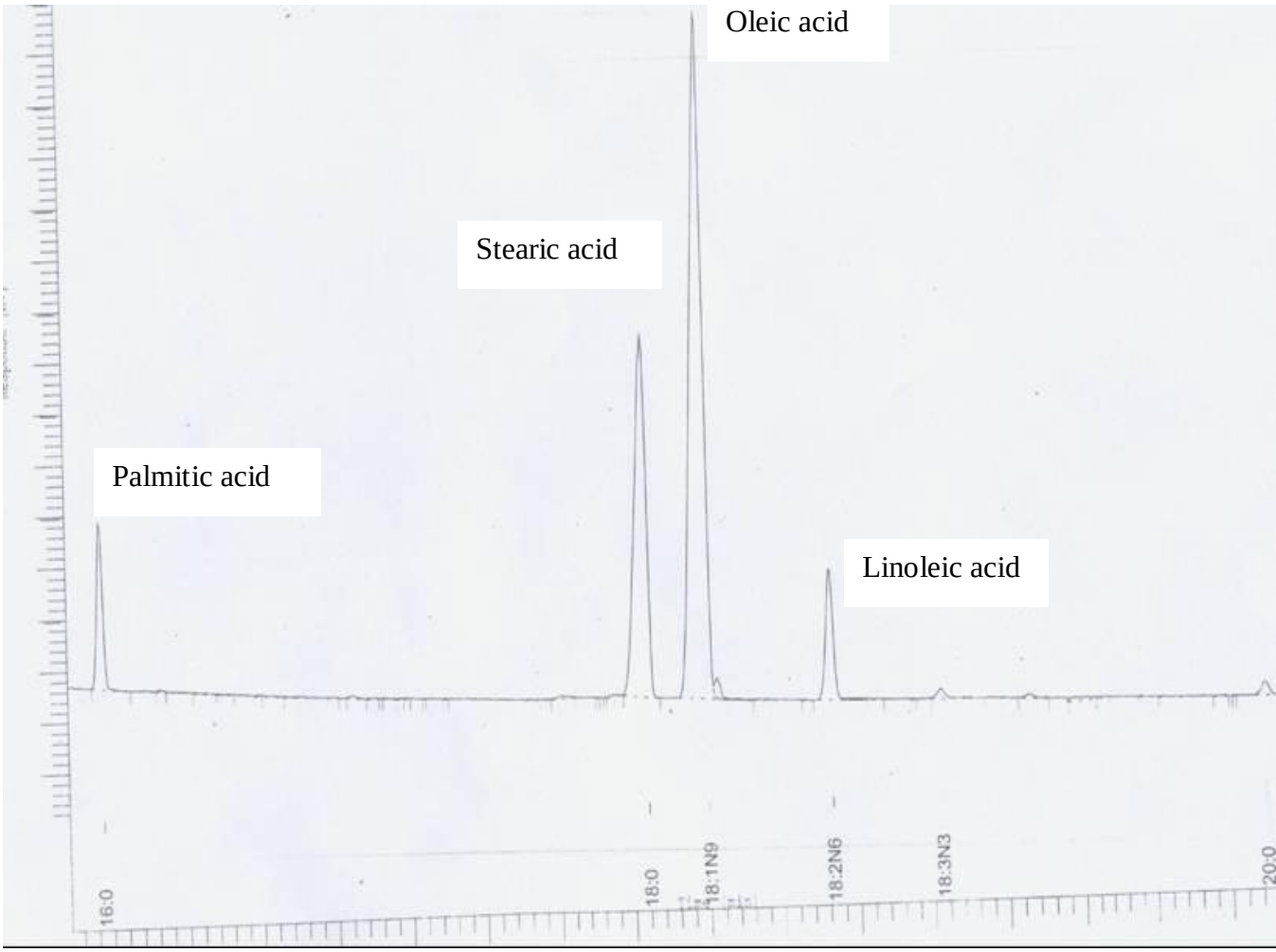

Figure IVb: GC Chromatogram for shea butter oil (FAME) extracted by cold pressing method

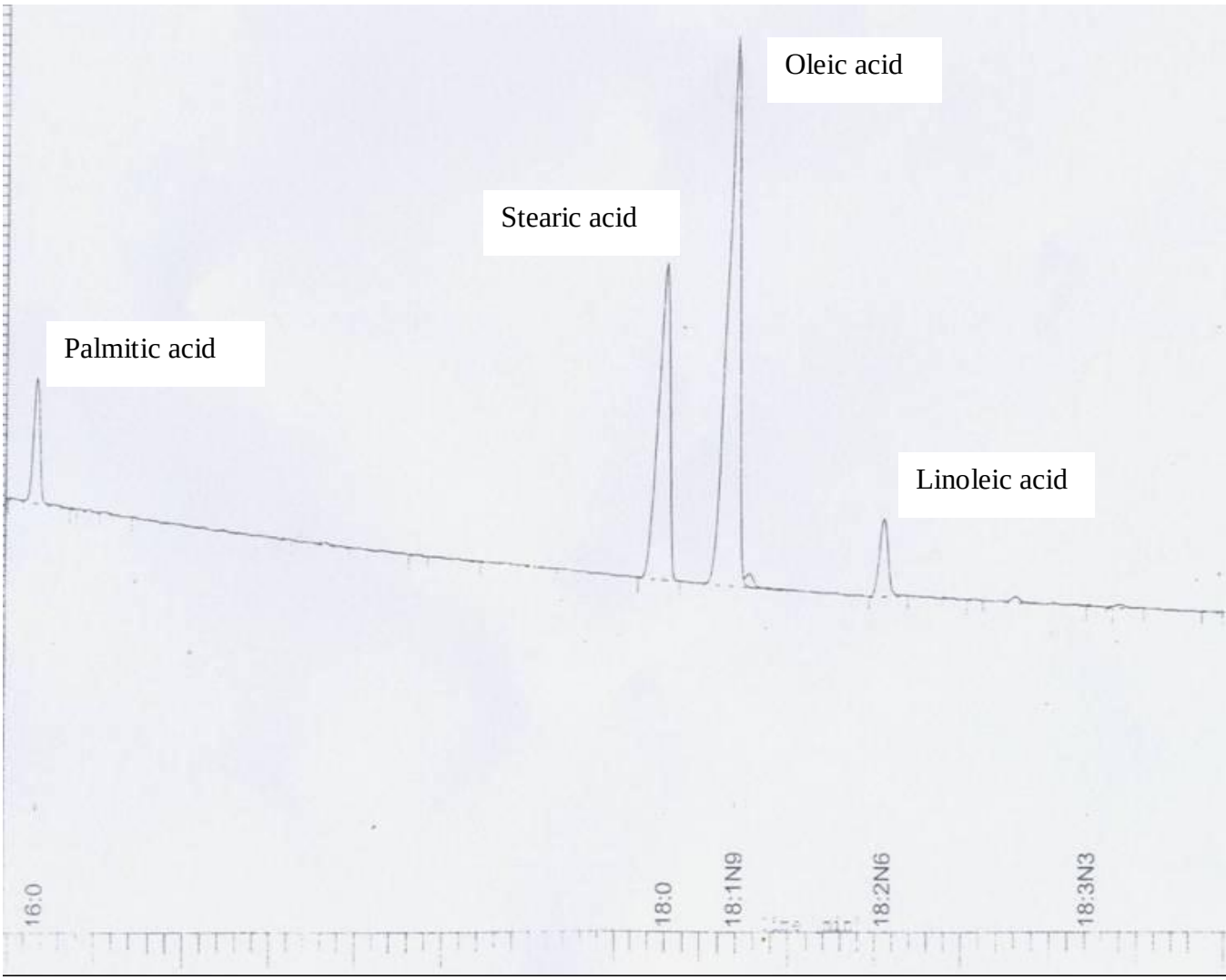

Figure IVc: GC Chromatogram for shea butter oil (FAME) extracted by traditional boiling method