Jatropha Oil Production as Biofuel for Shea Butter Processing Machine in Ghana: Quality Characteristics and Storability of the Derived Shea Butter

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DECLARATION

I hereby declare that this thesis is written independent of any unauthorised help under the supervision of Prof. Dr. rer. nat. Jürgen Ertel. All secondary material used have been duly acknowledged. The thesis is wholly mine and has not been part of any presentation for any other qualification in its present form or similar version.

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DEDICATION

This work is dedicated to my husband Mr. Kofi Mensah and our children Andrew William A. Kuttin Mensah, Benedicta M. Nyarko Mensah and David Wayne K. Butuacquah Mensah as well as my parents Mr. Joseph Kojo Anokye and Mrs. Agnes Tieku Anokye.

TO GOD BE THE GLORY!

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ABSTRACT (ENGLISH)

The ever-increasing price of fossil diesel oil, its availability and affordability has prompted the search for cheaper sources of diesel fuel in the country and especially in rural Ghana where it could be used by small to medium scale processors. The *Jatropha curcas* plant has been identified as the most suitable plant for biodiesel in Ghana, because it grows wild throughout the country and has superior yields to most energy crops in the country. The aims of this project were to provide a readily available and renewable fuel that will serve as a diesel substitute: to power diesel engines running equipment in a shea butter extraction unit at Gbimsi, to provide a readily available fuel that will serve as a kerosene substitute for lighting local lanterns, to evaluate the economic viability of the use of the biofuel as both diesel and kerosene substitutes in remote rural areas in Ghana. A pilot Jatropha plantation was established for the Gbimsi women's group. In addition to the plantation, a pilot processing unit was also established. The women were taken through series of training some of which included the extraction and utilization of Jatropha biofuel and soap making using the Jatropha oil. The Jatropha biofuel extracted by the women mixed with various amounts of mineral diesel oil was tested on lister-type diesel engines and also in lanterns to ascertain its performance. A combination of 30% mineral diesel oil: 70% Jatropha biofuel was found to be appropriate for running the diesel engines. Local lanterns were found to give smokeless light and were found to last four times longer than kerosene when the Jatropha oil was used. The cultivation of Jatropha plant and the processing of the oil provided an alternate livelihood for the Gbimsi women's group. In conclusion, the Jatropha biofuel helps in achieving energy security in communities that are otherwise inaccessible and constantly in search of regular supply of mineral fuels like diesel and kerosene. The press cake obtained after the production of the oil could be used as an organic fertilizer for improving soil fertility.

Questionnaires were administered to ninety (90) shea butter producers and ten (10) exporters selected at random from the Northern, Upper East, Upper West and Greater Accra regions of Ghana in order to gather information from the producers/users as well as exporters on the Knowledge, Attitude, Beliefs and Practices (KABP) of shea butter production, consumption and export. The outcome of the study suggested that shea butter export has increased tremendously over the past decade as a result of very high demand for the product from both the local and international markets. The existing and potential export maket for shea butter were identified to be Japan, United Kingdom, Netherlands and United States of America. In addition, the shea butter produced were evaluated for the quality characteristics as well as their storability in different storage (packaging) materials. These were conducted using standard analytical methods. The minimum quality requirement of shea butter for export are : Moisture (0.01-1.0%), Free fatty acid (3.5-4.0), acid value (1.0-10.0) and the product should not be dark in colour. The best packaging material used for the export of the product are metal drums and card boxes and the only constraint faced by the exporters is the cost of the packaging materials which is considered to be expensive. The producers in the studied communities treated shea butter as their main farming activity which has been passed on from one generation to the other, thus their main source of livelihood. This makes shea butter production an important employment avenue in the communities.

In an attempt to investigate the changes in chemical and physical properties of shea butter during storage, various chemical and physical quality indices were monitored. A 3 x 4 x 4 factorial experimental design with storage condition [open air (28-34°C), tropical ambient (26-31°C) and refrigeration (4-7°C) conditions], packaging material (metal cans, polyethylene bags, plastic containers and calabash), storage time (0,1,2 and 3 months) as variables was performed. Changes in the chemical and physical properties of the butter were observed during storage of the product under the different storage conditions and packaging materials. Storage caused slight increases in moisture content (0.01-0.07%), free fatty acid (3.29-4.38%), acid value 6.55-8.20%), iodine value

(59.86-60.06) and peroxide value (8.24-10.64 mEq/kg) within the three months storage period. Products stored under open air (28-34°C) conditions generally significantly ($p \leq 0.05$) affected the chemical properties of the butter during storage whilst those stored under ambient (26-31°C) and refrigeration (4-7°C) conditions did not have significant ($p \leq 0.05$) effect on the chemical properties. No wide variations in physical properties were noted for the products during storage under the different storage conditions and packaging materials.

Shea butter can be stored using all the four different packaging materials studied. However, it is highly recommended that the products are kept under tropical ambient (26-31°C) and refrigeration conditions (4-7°C) during storage. The best condition for the storage of shea butter is refrigeration which maintains the quality of the product during prolonged stored periods. Storage of the shea butter under open air (28-34°C) conditions allows for oxidative and hydrolytic rancidity rendering the products unsuitable for consumption after long storage periods.

ABSTRACT (GERMAN)

ABRISS

Die Dieselölpreisspirale, seine Verfügbarkeit und Erschwinglichkeit haben veranlasst, dass man auf der Suche nach billigeren Quellen von Dieselbrennstoff im Lande und besonderes in den ländlichen Gebieten von Ghana ist, wo ihn mittelständische Verarbeiter verwenden könnten. *Jatropha curcus* wurde als die geeigneteste Pflanze zur Gewinnung von Biodiesel in Ghana identifiziert, da sie überall im Land wild wächst und höhere Erträge als die meisten energiegewinnenden Saaten im Lande hat. Die Ziele dieses Vorhabens bestanden darin, einen leicht verfügbaren und erneuerbaren Kraftstoff zur Verfügung zu stellen, der als Ersatz für Diesel dient, z. B. für die bisher mit Diesel angetriebenen Kraftanlagen für die Verarbeitung von Sheabutter oder die Bereitstellung eines leicht verfügbaren Brennstoffs als Ersatz für Kerosin in herkömmlichen Lampen. Untersucht wird die Wirtschaftlichkeit des Einsatzes vom Biokraftstoff sowohl als Ersatz für Diesel als auch für Kerosin in weitgelegenen, ländlichen Gebieten von Ghana. Eine *Jatropha*-Pilotplantage wurde auch für die Gbimsi-Frauengruppe gegründet, wobei außer der Plantage auch eine verarbeitende Anlage errichtet wurde. Die Frauen wurden in einer Reihe von Veranstaltungen ausgebildet, insbesondere in der Extraktion und Verwendung von *Jatropha*-Biokraftstoff sowie der Seifenherstellung mittels *Jatropha*-Öl. Der von den Frauen gewonnene *Jatropha*-Biodieseltreibstoff wurde mit verschiedenen Mengen von Mineraldieselöl gemischt und an Listertyp-Dieselmotoren sowie in Laternen getestet, um dessen Eignung festzustellen. Eine Mischung aus 30% Mineraldieselöl / 70% *Jatropha*-Biodiesel wurde zum Antreiben der Dieselmotoren als geeignet ermittelt. Zudem wurde festgestellt, dass bei Verwendung von Jatropha-Öl herkömmliche Laternen keinen Rauch von sich geben und viermal länger halten.

Der Anbau von *Jatropha*-Pflanzen und deren Verarbeitung zu Öl bieten der Gbimsi-Frauengruppe einen alternativen Lebensunterhalt. Zusammengefasst trägt *Jatropha*-Biodiesel zur Gewährleistung der Energiesicherheit in den Gemeinschaften bei, die sonst mit Brennstoff schwer versorgbar sind

und die daher immer auf der Suche nach einer regelmäßigen Lieferung von Mineralbrennstoffen wie Diesel und Kerosin sind. Der mit der Herstellung von Öl gewonnene Kuchen, könnte als organisches Düngungsmittel zur Verbesserung der Bodenfruchtbarkeit dienen.

Fragenbögen wurden an neunzig (90) Sheabutterhersteller und an zehn (10) Exporteure verteilt, die aus den *North- Upper East-*, *Upper West-* und *Greater Accra*-Regionen von Ghana willkürlich ausgewählt wurden, um sowohl von den Herstellern/Benutzern als auch von den Exporteuren Informationen über Kenntnis, Geisteshaltung, Anschauungen und Praktiken bezüglich Herstellung, Anwendung und Ausfuhr von Sheabutter zu erhalten. Ergebnis der Studie ist, dass die Ausfuhr von Sheabutter über das letzte Jahrzehnt enorm gestiegen ist und zwar wegen der sehr hohen Nachfrage des Produktes sowohl von den Inlands- als auch von den Auslandsmärkten. Japan, Großbritannien, die Niederlande und die Vereinigten Staaten von Amerika (USA) wurden als die gegenwärtigen und zukünftigen Exportmärkte für Sheabutter festgestellt.

Außerdem wurde die produzierte Sheabutter im Hinblick auf Ihre Qualitätsmerkmale als auch ihre Haltbarkeit in verschiedenen Verpackungsmaterialien untersucht. Die Auswertung wurde mittels klassischer und analytischer Methoden durchgeführt. Die Mindestanforderungen an die Qualität von Sheabutter für den Export sind: Feuchtigkeit (0.01-1.0%), fettfreie Säure (3.5-4.0), Säurewert (1.0-10.0) und die Farbe des Produkts soll nicht dunkel sein. Die besten, für den Export des Produktes verwendeten Materialien sind Metallfass und Pappkarton und das einzige, den Exporteuren entgegenstehende Hemmnis ist der hohe Kaufpreis der Verpackungsmaterialien. Die in den Gemeinschaften dieser Studie ausgeübte Verarbeitung von Sheabutter erfolgt nach Verfahren, die von Generation zu Generation überliefert wurden. Die Produktion von Sheabutter wird als Haupteinnahmequelle zum Bestreiten des Lebensunterhalts gesehen. Dies macht die Produktion von Sheabutter zu einem wichtigen Faktor für die Beschäftigungssituation in den Gemeinschaften.

Bei einem Versuch, die Änderung der chemischen und physikalischen Eigenschaften der Sheabutter bei der Lagerung zu untersuchen, wurden verschiedene chemische und physikalische Qualitätsindexziffern kontrolliert. Ein 3 x 4 x 4 faktorisierter Experimentalplan wurde durchgeführt mit den Variablen: Lagerungsbedingung [Voraussetzungen: im Freien (28-34ºC), tropische Raumumgebung (26-31ºC) und Kühlung (4-7ºC)], Verpackungsmaterialien (Metallkasten, Polyäthylentaschen, Kunststoffbehälter und Kalabasse) und Lagerungszeit (0, 1, 2 und 3 Monate). Änderungen an den chemischen und physikalischen Eigenschaften der Sheabutter wurden bei der Lagerung des Produktes unter verschiedenen Lagerungsbedingungen und Verpackungsmaterialien untersucht. Die Lagerung verursachte eine leichte Erhöhung des Feuchtgehalts (0,01-0,07%), freier Fettsäuren (3,29 bis 4,38%), des Säurewerts (6,55 bis 8,20%), der Jodzahl (59,86 bis 60,06) und Superoxydwert (8,24 bis 10,6 mEq/kg) innerhalb der dreimonatigen Lagerungszeit. Im Allgemeinen beeinflussten wesentlich ($p \leq 0,05$) die Bedingungen der im Freien gelagerten Produkte die chemischen Eigenschaften der Sheabutter bei der Lagerung, während die in Raumumgebung (26ºC bis 31ºC) und unter Kühlung (4ºC bis 7ºC) gelagerten Produkte keinen wesentlichen Einfluss ($p \leq 0,05$) auf die chemischen Eigenschaften hatten. Bei der Lagerung der Produkte unter den verschiedenen Lagerungsverhältnissen und Verpackungsmaterialien wurden keine beachtlichen Änderungen der physikalischen Eigenschaften der Produkte festgestellt.

Sheabutter kann zwar mittels aller vier verschiedenen untersuchten Verpackungsmaterialien gelagert werden, aber es ist besonders empfehlenswert, dass die Produkte bei der Lagerung unter den Verhältnissen der tropischen Raumtemperaturumgebung (26ºC bis 31ºC) mittels Kühlung (4ºC bis 7ºC) aufbewahrt werden, wodurch die Qualität des Produkts bei der Lagerung über längere Zeit erhalten bleibt. Die Lagerung unter den Verhältnissen im Freien (28ºC bis 34ºC) bewirkt durch Oxidation und Hydrolyse hervorgerufene Ranzigkeit, welche die Produkte bei der Lagerung über eine längeren Zeitraum für den menschlichen Verzehr ungeeignet macht.

ACRONYMS/ABBREVIATIONS

ADRA	Adventist Development and Relief Agency
ABC Ltd	Aburaman Biofuels Company Limited
AIBP	Anuanom Industrial Bio-Products Limited
ALP	Alternative Livelihood Project
AOAC	Association of Analytical Chemists
ASTM/SAYBOLT	American Standard for Testing Materials Analytical Equipment
B1 Ghana Ltd	Biodiesel One Ghana Limited
CO	Carbon Monoxide
FFA	Free Fatty Acid
GEF	Global Environment Facility
GRATIS	Ghana Regional Appropriate Technology Industrial Services
GRESDA-GH	Gender Responsive Renewable Energy Systems Development and Application Ghana
GSB	Ghana Standards Board
HDPE	High Density Poly Ethylene
HIPS	High Impact Poly Styrene
IC	Internal Combustion
IMC	Intermediate Moisture Content
IUPAC	International Union of Pure and Applied Chemists
JES	Jatropha Energy System
KITE	Kumasi Institute of Technology and Environment
LDPE	Low Density Poly Ethylene
NOx	Nitrogen Oxide

NYEP	National Youth Employment Programme
PET	Poly Ethylene Terephtalate
PP	Poly Propylene
PVC	Poly Vinyl Chloride
SVO	Straight Vegetable Oil
TCC	Technology Consultancy Center
TOR	Tema Oil Refinery
UBHC	Unburned Hydrocarbon emissions of Biofuel
UNDP	United Nations Development Program
UNIDO	United Nations Industrial Development Organization
UNIFEM	United Nations Development Fund for Women
¢	Ghanaian Cedi
$	American Dollar

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1.0 INTRODUCTION

Modern sustainable energy technologies have proved to be essential for the provision of improved energy services, which are necessary for poverty reduction efforts in the rural and urban areas of Ghana. The concerted efforts for increased uptake and use of modern energy technologies demand an integrated approach that takes into consideration economic and social development needs of the rural women. The majority of the rural population has a lower purchasing power and depends mainly on wood fuel for cooking, kerosene for lighting, diesel for running agro-processing machines, all of which have negative effects on the quality of life of the rural poor. Energy is a crucial input in the efforts of alleviating poverty but most efforts of energy development have been directed towards commercial energy services such as fossil fuels and grid electricity, which the rural poor cannot afford. Thus, development of biomass energy, which is consumed by 85% of the population, is still inadequate and this study would help contribute towards alleviating the energy problems of the rural and urban areas. The study will envisage strategies that contribute to greater uptake of renewable energy technology such as Jatropha oil as a biofuel in rural areas of Ghana. The study will ensure technology transfer through demonstrations, disseminations, capacity building, monitoring and evaluation of activities. This will build confidence of entrepreneurs and users on the use of the oil.

Small and medium scale food processing is a major economic activity for women in Ghana. The introduction of improved processing technologies to reduce the drudgery of women in the area of food processing and technology transfer has resulted in, for example, the use of mechanized processes run by either electric motors or by diesel engines in remote areas where there is no electricity. There is also the dependence of most rural food processors on diesel for the operation of diesel engines to run food processing equipments such as grinding machines and graters. With the rising cost of petroleum products in Ghana, the continued use of diesel to power processing equipment will result in an increase in the cost of production, which will result in the high cost of products.

The search for alternative sources of fuel to the current fossil fuels used has been reported by various authors. The *Jatropha curcas* plant has been found to be the most suitable plant for bio-fuel production in Ghana. Biofuel from the *Jatropha curcas* plant has been found to be a better option since its cultivation and oil extraction could, in addition to reducing oil import bill, have a significant amount of local content thereby contributing to poverty alleviation, combat desertification, and contribute to sustainable development while empowering women and children in Ghana. The production of bio-energy will have various positive effects for Ghana which has no own petroleum resources. The necessary importation of fossil fuels is a constant socio-economic effort, which has the same well-known effects as in other developing countries without petroleum: fuel shortage, high trade deficit, foreign indebtedness, and lack of foreign exchange.

Jatropha Curcas L. is a perennial shrub that grows well in semi-tropical conditions, on poor soils and requires little care. It can easily be integrated into the rural economy at the village level. Under optimal conditions, Jatropha seed yields of up to 8 tons can be achieved, resulting in oil yields of up to 2200 kg per hectare. The crop can be grown as protective hedges around fields, where they protect food crops against predators, or in dedicated plantations. The role of *J. curcas* as a substitute for diesel is very remarkable. Augustus *et al.* (2002) reported the energy value of the seed: the gross heat value of the seed (0% moisture content) is 4980.3 cal/g (20.85 MJ/kg), which is higher than the heat value of lignite coal, cattle manure and comparable to the heat value of corn cobs (10% moisture content). The high gross heat value can be attributed to the presence of a high level of oil, polyphenol and hydrocarbon in the seed. The gross heat value of the oil fraction is 9036.1 Cal/g (37.83 MJ/kg), which is higher than that of anthracite coal. The gross heat value of the hydrocarbon fraction was 9704.4 Cal/g (40.63 MJ/kg), which is higher than that of anthracite coal and comparable to that of crude oil. These results indicate that *J. curcas* may serve as an intermediate source of energy.

Shea butter is a soft paste or melted fat with a yellowish colour and a characteristic pleasant odour that is used for a variety of purposes in Ghana. Crude shea butter has natural antioxidant properties due to its content in tocopherols. Its high content of unsaponifiable fats is remarkable in comparison with other oils for their industrial applications. The importance of shea butter as a raw material is much appreciated in both the cosmetic and pharmaceutical industry. Shea butter is generally produced in Ghana and used by both rural and urban folks for a variety of applications. It is utilized in all the ten regions of Ghana, but the highest quantity is known to be used in the Northern regions. In the northern regions of Ghana, shea butter is the cooking oil mostly used for food preparation and it is estimated that its consumption is about 4.6 kg per month for a family of five (Atta, 1978). Traditionally, the butter is also used both in the Southern and Northern Ghana as pomade and ointment because of its cosmetic and medicinal properties. To develop further markets for the local processors, attempts are being made by a number of non-governmental organisations to identify overseas market for the women processors.

Traditional processing of shea butter for export in Ghana has been a daunting problem for exporters for years. Some institutions in Ghana including the Technology Consultancy Center and GRATIS Foundation have successfully developed and field-tested a simple process known as the Intermediate Moisture Content (IMC) method for the extraction of shea butter in their attempt to remove the bottlenecks in the traditional processing method. Results of field-tests carried out in Yipelgu in the Northern Region indicate that the new process is technically viable (Abu-Bakr *et al.*, 1998). Thus, there is increased production of shea butter, which needs to be scientifically packaged to facilitate women's access to better income from the international market. In the manufacturing and export of shea butter products, packaging is an essential input. Efficient packaging is a necessity for almost every type of product. It is an essential link between the product maker and his customers (Paine, 1996). Basically it facilitates the carriage and protection of the products against risks such as damage, spoilage and theft in the storage and distribution channel. In Ghana, currently, shea butter is mainly packaged in calabash for sale.

Traditional processes of vegetable oil manufacture have given way to more advanced methods such as the screw press and solvent extraction methods; however, very little attention has been paid to the old processing methods for shea butter. Nevertheless, the traditional process has continued to serve the needs of the local population who use shea butter for domestic purposes. The traditional shea butter extraction, using indigenous method, still accounts for about 80% of the total production in Ghana, and is the leading income generating activity of rural women in the Northern and Upper Regions of Ghana (Atta, 1978). A few companies in Tamale, the regional capital of northern Ghana act as intermediaries between the women and the international market. According Dr. David Mensah of Canada Fund (Personal communication, 1999), between 1994 and 1999, Body Shop of United Kingdom purchased 69 tonnes of shea butter from ten Ghanaian women groups, and order for 50 tonnes butter was placed by Body Shop during the year 2000 from Ghana. Table 1 shows the quantity of shea butter purchased by Body Shop of London from the Ghanaian market (Tunteiya) between 1994 and 2007.

Table 1. Shea Butter Purchases from Tunteiya between 1994 and 2007

Year	QUANTITY PURCHASED (Metric Tonnes)
1994	5
1995	7
1996	7
1997	10
1998	10
1999	30
2000	50
2001	67
2002	84
2003	93
2004	127
2005	143
2006	156
2007	170

Source: Abu-Bakr *et al.* 1998 and updated data from field (unpublished)

The quantity of shea butter purchased from Tunteiya women's group in the northern region of Ghana increased tremendously from 5 metric tonnes in 1994 to 170 metric tonnes in 2007, indicating that the shea butter market has gained a high level of recognition which can be further improved if suitable packaging systems are developed to help enhance the shelf life of the product. The local or traditional extraction can be described as having low efficiency, long processing time, high water consumption, high firewood consumption and high smoke production which constitute health hazards. The traditional process consists of seven unit operations, namely, gritting, roasting, milling, kneading, washing, cream boiling, and clarification. This processing method has an average extraction efficiency of 62%. Among the drawbacks of the process are the arduousness of the operations, lengthy processing time, and low scale of production. It takes approximately 6 hours for a hard working woman to process 10 kg of kernels. The process consumes 180 litres of water and 72 kg of firewood for 1 bag (85 kg) of kernels processed. Both water and firewood are scarce in the processing areas of the Northern and Upper Regions of Ghana. Other problems include the excessive exposure of processors to heat and smoke, and exploitation of their time and skills by the local companies which export shea butter. Studies conducted by Atta (1978) showed that the women processors lose about 5 years of their health time by inhaling smoke and exposing themselves to heat. Women do not have enough working capital for their operations, so they are manipulated by exporters to produce butter for them at very cheap cost, and under conditions that pose health hazards to them. In Tamale, hundreds of women are seen queuing daily for a chance to produce butter for a company just to be given a daily wage. Sometimes only 200 women out of 600 women in the queue are selected and given the opportunity to produce butter using traditional aqueous processing method.

In an attempt to remove the production bottlenecks in the traditional method, and other problems faced by processors, the GRATIS Foundation and Technology Consultancy Center (TCC) have successfully developed a manually operated bridge press for the extraction of shea butter using the Intermediate Moisture Content (IMC) method which has an average extraction efficiency of 67 %. The new method, which was successfully field tested in Gbimsi a village in the Northern Region is currently used by some women processors in the region. It involves grinding dry kernels (normally at a moisture content of between 4-6 %) into paste using a local plate mill. The paste obtained soon after milling, is usually at a temperature of about 70 °C, and allows for the processing of the paste without any further heat treatment. To prepare it for pressing, its moisture content is raised to 12 % by kneading with a predetermined amount of hot water. The moisturized paste, upon attaining a temperature of about 60 °C is put in small bags, and pressed in a bridge press to release the oil.

Advantages of the IMC method over the traditional process include the following:

i. Increase in extraction efficiency by 5% of the normal extraction rate.

ii. Increase in daily production capacity by 200%.

iii. Drastic decrease in firewood consumption: About 8 kg of firewood for the IMC method against 72 kg for the traditional, for every 85 kg of kernels processed.

iv. Drastic decrease in water use. About 8 litres of water for IMC method against 160 litres for the traditional method, for every 85 kg of kernels processed.

v. Reduction in the extraction operations from 7 to 5 by the removal of roasting and cream boiling operations, both of which are time-consuming, waste a lot of firewood and water, and expose the women to excessive heat and smoke.

vi. Higher consumer preference for the butter processed from using the mechanised method due to its milder shea smell.

vii. The Process is environmentally friendly. It saves wood fuel and conserves water. It does not produce any effluent, but rather the cake produced after the oil extraction can be dried and used as fuel.

Thus with the breakthrough in technology development the increased volume of shea butter being produced currently should be properly packaged to enhance the shelf life and secure a better place in the international market for the local processors in Ghana. Packaging has become an important industry in the industrialized countries of the world and it provides lucrative employment for millions of people. With the production of shea butter, Ghana's packaging industry has been dormant in relation to the budding state of industrialization in the country. The steady growth of the manufacturing of shea butter and non-traditional exports in Ghana calls for the need for high quality and adequate packaging materials. Several packaging companies have been established in Ghana for the manufacture of diverse types of packaging materials. These companies include the Poly Group of companies which have been in operation since 1996 and two other industries namely Poly Products and Poly Sacks established since 1976 to produce polyethylene bags according to customers' specifications. In order to add value and quality to the shea butter products processed by women as well as empower them economically, there is the urgent need to look at the packaging of shea butter critically and find solutions to help package them to meet international standards.

The main objectives of this work were to produce renewable bio-fuel that will serve as a diesel substitute to power diesel engines running equipment in a shea butter extraction unit at Gbimsi, to evaluate the quality characteristics and storability of the shea butter produced and to determine the most appropriate packaging materials that can be used to obtain a more acceptable product quality that conforms to international standards.

1.1 Specific Objectives

The specific objectives of the study were to:

i. produce a renewable bio-fuel using *Jatropha curcas* that will serve as a diesel substitute to power diesel engine equipment used in the extraction of shea butter in Northern Ghana.

ii. study the physical and chemical properties of the shea butter produced using the Jatropha biofuel as engine oil.

iii. study the effect of storage techniques (temperature and packaging material) on the quality characteristics of shea butter.

iv. select and recommend appropriate and competitive packaging system for use by shea butter processors.

2.0 LITERATURE REVIEW

2.1 The *Jatropha Curcas* Linnaeus Plant

Jatropha curcas is a non-edible, oil-bearing and drought resistant hardy shrub with ecological advantages (Fig. 1). It belongs to the family Euphorbiaceae and is cultivated in Central and South America, South East Asia, India and Africa (Martinez-Herrera *et al.*, 2006). It is a small tree or large shrub, up to 8 m tall and with a trunk diameter up to 20 cm. The trunk is straight, branching low above the ground; bark is thin and yellowish. The leaves are 6 x 15 cm and lobed and arranged alternately. The flowers are small and greenish. The fruit is a grey-brown capsule, up to 4 cm long; it is normally divided into 3 cells, each containing one seed. The seeds are black, about two cm long and one cm thick (Fig. 2). There are 1000-2400 seeds per kg. The seed resembles the castor seed in shape, but is smaller in size and of dark brown colour. The seed yield is up to 5 tons/hectare (Heller, 1996). The seed kernels contain up to 60% oil with a fatty acid composition similar to that of common edible oils (Makkar *et al.*, 1997). The root system of Jatropha plants (seedlings) consists of three to four lateral roots and a vertical taproot which reaches 5m into the soil (Heller, 1996).

The plant grows quickly, survives in poor stony soils, and is resistant to drought and diseases. It does not compete with conventional food or feed crops for land and water, and thus it could be an ideal choice to make use of vast land resources that are presently underutilized (Makkar *et al.*, 1997). In tropical countries it is well known for its medicinal properties and as an oil seed. It is also used as a live hedge (not browsed by livestock) and is propagated using branch cutting or sown by direct seeding (Heller, 1996).

Figure 1. Fruits of *Jatropha Curcas* L.

Source: From Author's Field Work

Figure 2. Jatropha Seeds Used for Oil Extraction

Source: From Author's Field Work

2.2 Historical Background of *Jatropha Curcas*

The plant was originally found in Central America but now grows in several regions across the world. Figure 3 shows the spread of the plant in Africa, where it is believed to have been brought by Portuguese seafarers (Heller, 1996).

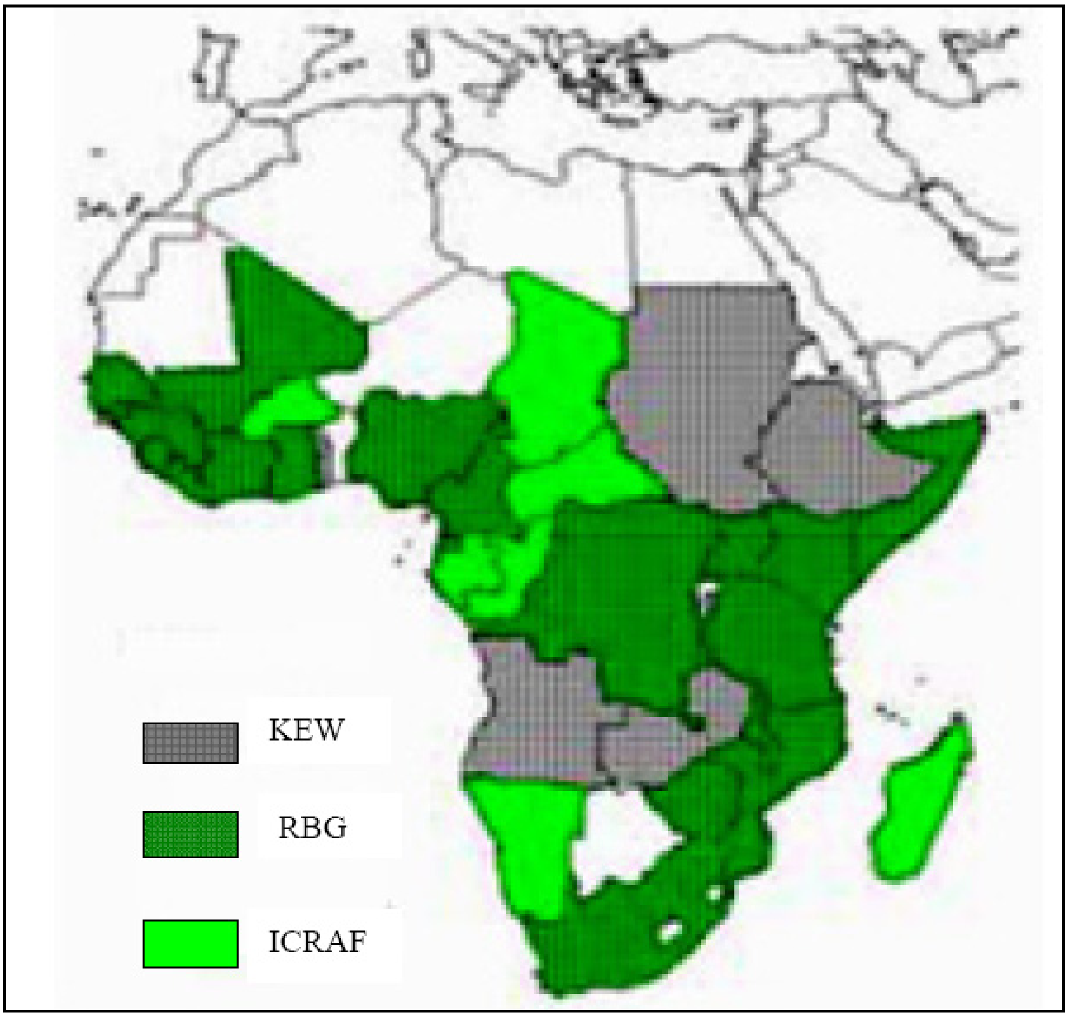

Figure 3. Geographical Location of Jatropha, According to International Center for Research in Agro Forestry (ICRAF), Royal Botanical Gardens and Kew

Source: Research Group International Programs (IP) (2002).

There are also reports on the use of Jatropha oil as a diesel substitute in Mali during the Second World War and also the fact that Jatropha oil exports contributed 60% to the agricultural exports of Cape Verde in the nineteenth century, and 5 to 15% of the total reforested area in 1989 and 1990 were planted with Jatropha, mainly for erosion control purposes (Heller, 1996).

2.3 Distribution and Habitat of *Jatropha curcas*

It is still uncertain where the centre of origin is, but it is believed to be Mexico and Central America. It has been introduced to Africa and Asia and is now cultivated world-wide. This highly drought-resistant species is adapted to arid and semi-arid conditions. The current distribution shows that introduction has been most successful in the drier regions of the tropics with annual rainfall of 300-1000 mm. It occurs mainly at lower altitudes (0-500 m) in areas with average annual temperatures well above 20°C but can grow at higher altitudes and tolerates slight frost. It grows on well-drained soils with good aeration and is well adapted to marginal soils with low nutrient content.

2.4 Harvest of *Jatropha Curcas*

When the fruits begin to open, the seeds inside are mature. Collection is best done by picking fruits from the tree or hitting and shaking the branches till the fruits break off. Seeds collected from live fences can normally be reached by hand. For taller trees it is possible to collect the fruits in a small bag that is attached to a stick. In Costa Rica it is estimated that a tree produces about 30 kg fruits per year or about 12 kg seed. The yield per hectare is about 4800 kg seed.

2.5 Uses of *Jatropha Curcas*

Jatropha curcas is a multi-purpose plant, with many possible applications. The application of Jatropha species (Euphorbiaceae) in traditional medicine has been frequently reported, e.g. *Jatropha curcas* is used in Nepal to treat malarial fever (Manandhar, 1989), and in Egypt to treat arthritis, gout and jaundice (Khafagy *et al*., 1977). In Indonesia, the latex of *J. multifida* is externally applied to (infected) wounds and ulcers (Kosasi *et al.,* 1989). Although seed oils of *J. multifida*, *J. podagrica, J. curcas,* and *J. gossypifolia* are known to possess toxic, skin irritant and tumour-promoting properties due to the presence of phorbol esters (Adolf *et al.*, 1984; Biehl. and Hecker, 1986), several compounds with anti-tumour activities have also been found in Jatropha species. For instance, from the roots of *J. gossypifolia*, jatrophone (a macrocyclic diterpenoid) and 2fl-hydroxyjatrophone were isolated (Kupchan et al., 1976, Taylor *et al.,* 1983) and from *J. macrorrhiza* acetylaleuritolic acid (a triterpenoid) and jatropham (a lactam), which all displayed antileukemic activity (Torrance *et al.,* 1977, Wiedhopf *et al.,* 1973).

It is also useful for the prevention and control of soil erosion, as living fence and as source of oil, which can be converted to bio-diesel meeting the standards of the USA, Germany and the European Standard Organization. JCL is easy to propagate, has few diseases and pests and grows in a wide range of rainfall regimes, from 200 to 1500 mm per annum (Openshaw, 2000).

2.6 The Jatropha Production Chain

The Jatropha plant is easy to establish and drought resistant. It can grow up to 8 metres high, and is not browsed by animals. It has been traditionally used as a hedge. It can live up to 50 years and can produce seeds up to three times per annum (Chachage, 2003). Figure 4 shows the main stages in the Jatropha production chain, from seed to end product. There are many possible uses for Jatropha. The figure only shows those applications that were actually in use or under active exploration in Tanzania and Ghana at the time of the study in mid 2005.

Under cultivation come the activities pertaining to the growing of the Jatropha plant and the harvesting of the seeds. Jatropha is grown in nurseries from seeds. In Tanzania and Ghana this is done by women's groups. Villagers also take cuttings and plant them. The cuttings take less time to establish, but the seed-grown Jatropha bushes are stronger because they develop tap roots. The seed yields reported for different countries and regions range from 0.1 to 15 t/ha/y (Heller, 1996; Jones & Miller, 1993). Apparently the yield depends on a range of factors such as water, soil conditions, altitude, sun and temperature. No systematic research seems to have been conducted yet to determine the influence of these factors and their interactions. Harvesting of the seeds takes place during the dry season, normally a quiet period for agricultural labour. The seeds contain about 30% oil. The oil contains a toxic substance, curcasin, which is a strong purgative (Chachage, 2003). The seedcake which is left after pressing is relatively rich in nitrogen.

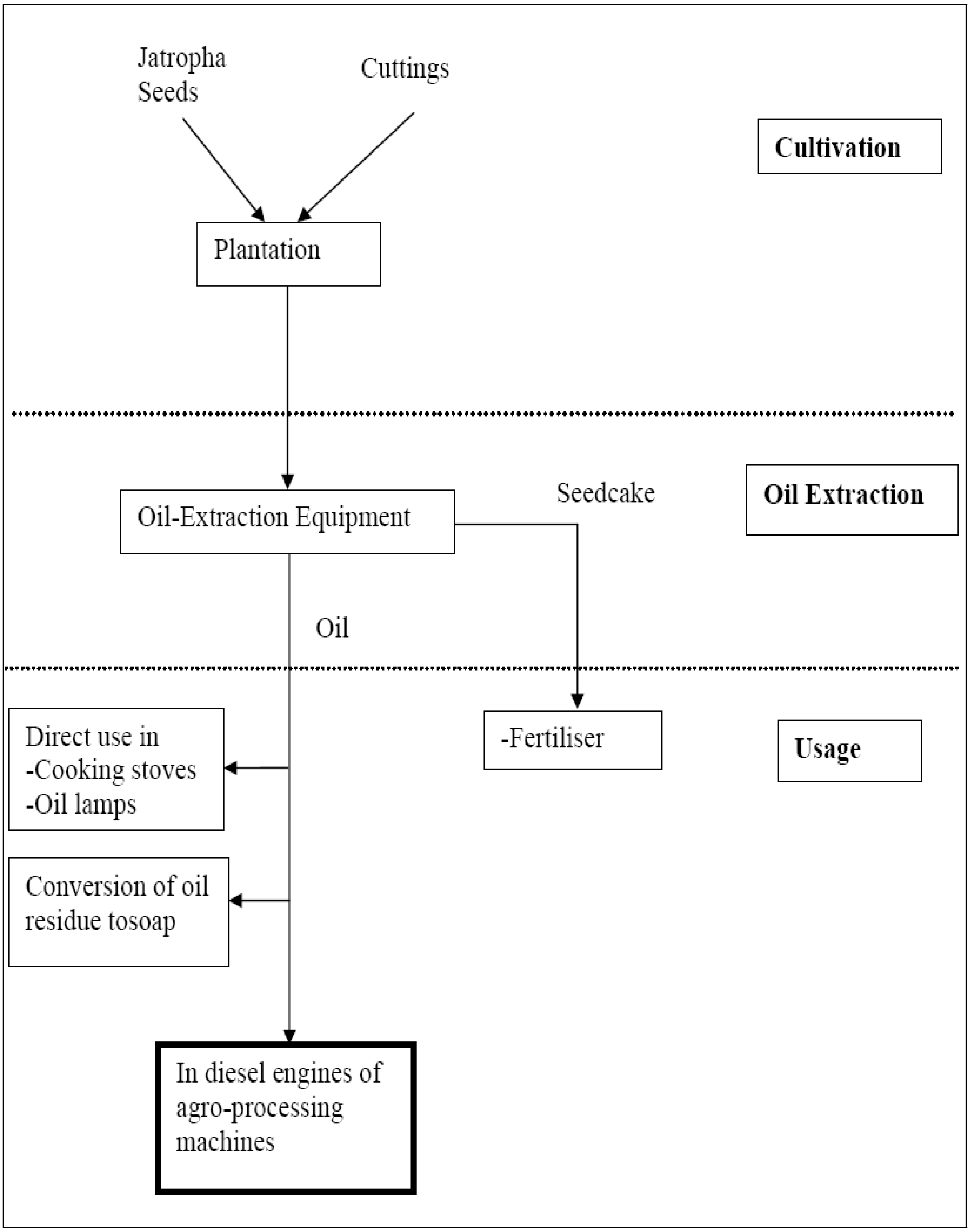

Figure 4. Jatropha Production Chain as Used in Gbimsi

Source: From Author's Field Work

2.7 Chemical, Toxic Composition of *Jatropha Curcas* Seeds

As already mentioned, the seeds of physic nut are a good source of oil, which can be used as a diesel substitute (Martinez-Herrera *et al*., 2006). They are used also in medicines, and soap and cosmetics manufacture in various tropical countries. Although the seed meal, after extraction of oil, is rich in protein, it is toxic to rats, mice and ruminants and therefore cannot be used as an animal feed. Several cases of *J. curcas* nut poisoning in humans after accidental consumption of the seeds have been reported with symptoms of giddiness, vomiting and diarrhoea and in the extreme condition even death has been recorded (Becker & Makkar, 1998). The meal has high trypsin inhibitor and lectin activities, which could be inactivated by heat treatment. In addition, high concentration of the antimetabolic, metal-chelating and heat-stable factor, phytic acid, has been reported in *J. curcas* meal (Makkar *et al.,* 1998). Apart from these, phorbol esters that are present at high levels in the kernels have been identified as the main toxic agent responsible for toxicity (Adolf *et al.,* 1984; Makkar *et al.,* 1997). After removing the toxic and heat-stable factors through solvent extraction, using 92% methanol, the extracted meal was found to be non-toxic to rats (Makkar & Becker, 1997).The defatted meal has been found to contain a high amount of protein, which ranged between 50 % and 62 %. Except for lysine, all other essential amino acids in *J. curcas* meal protein have been reported to be in higher concentrations than those of the FAO reference pattern suggested for pre-school children (Makkar *et al*., 1998). In addition to the more common toxic varieties, a non-toxic variety of *J. curcas* seeds, that contained negligible amounts of phorbol esters, but similar levels of trypsin inhibitors, lectin activity and phytic acid compared to the toxic variety, has been reported from the Papantla region of Veracruzstate in Mexico

(Makkar & Becker, 1999). The non-toxic seed kernels are consumed by local people after roasting. The hydro-thermally processed defatted meal of the non-toxic variety did not show any toxicity to rats (Makkar & Becker, 1999). However, the growth rates of fish fed diets containing heated Jatropha meal were found to be lower than the unheated Jatropha meal group (Makkar & Becker, 1999). The decrease of growth rate was also related to increase in the time of heat treatment. Though various processing techniques have been attempted, no treatment has been successful in completely eliminating the antimetabolic factors and toxic principles of defatted Jatropha kernel meal of non-toxic and toxic varieties.

2.8 The Jatropha Energy System (JES)

The Jatropha Energy System covers 4 main aspects of rural development: promotion of women sustainable livelihood (local soap production); poverty reduction (protecting crops and selling seeds, oil and soap); erosion control (planting hedges); energy supply for the household and stationary engines in the rural areas. The obvious advantage of this system is that all the processing procedure, and thus all added value, can be kept within the rural area or even within one village. No centralised processing is necessary.

The JES is based on several sub-systems, each with associated activities which allow for different implementation options, and where each module can be operated independently, offering its own potential economic benefits. When these activities are integrated into one system, more value is added. The JES offers a decentralized and localized energy option which empowers rural communities: it reduces their dependence on imported fuels, prices of which are highly volatile, given irregular supplies, bad infrastructure and the remoteness of the communities from urban centres. Given the likelihood of oil prices reaching ever-higher levels in the future, a localized biofuels production system becomes increasingly attractive. Moreover, the system diminishes their reliance on State actors and the culture of political promises, which are rarely realised. Unlike other decentralized energy systems, the JES is sustainable in the true sense of the word, for it relies on local knowledge and skills. The transfer of knowledge needed to introduce the system is very limited, whereas the introduction of solar, micro-hydro or wind power systems to small communities requires outside and continuous technical expertise. It moreover offers ecological advantages (retroactively or proactively combating erosion and desertification) and allows local communities to gain full ownership of the technology, in such a way that they can easily make decisions about the expansion and replication of the module, according to their own needs. This "bottom-up" approach has the potential to actively engage communities in producing their own energy (which is less likely with more "static" technologies such as wind power and hydro-electric power). Finally, as a carbon dioxide neutral system, the JES offers a renewable source of energy, based on simple plantations of the energy crop, which can be fully integrated in the village's existing practices.

2.9 Implementation Strategies of the Jatropha Energy System

The first step in the introduction of a Jatropha Energy System consists of building a reliable source of Jatropha seeds (Fig. 5). Producing Jatropha seedlings at the village level could become a highly profitable activity in itself: seedlings can be sold to plantation owners, or they may be used as natural hedges to protect other crops. Several micro-entrepreneurial activities surrounding the cultivation and trade of these mere seedlings have proved to be successful. Jatropha also makes for a suitable base-crop for intercropping systems. Even though Jatropha is well known in many tropical countries, at the first stage of the introduction of a JES, a constant and reliable source of seeds must be assured, creating the need for a dedicated Jatropha-plantation. Jatropha seeds from hedges could be collected by households once the JES is well established, after which they could be exchanged in a kind of simple "seeds for light" program. For the system to power more community services and machines, a configuration with local plantations can easily be implemented. In order to support a single power unit with a diesel engine running around 5 hours a day, an average of 4 hectares are needed. In itself, the cultivation of mature Jatropha trees becomes a profitable activity. After three years, Jatropha plants start to yield, reaching maturity in the 5th year. The seeds from Jatropha are bought either directly by engine owners or by independent millers who process them into biofuel since the cost of Jatropha oil is lower than diesel.

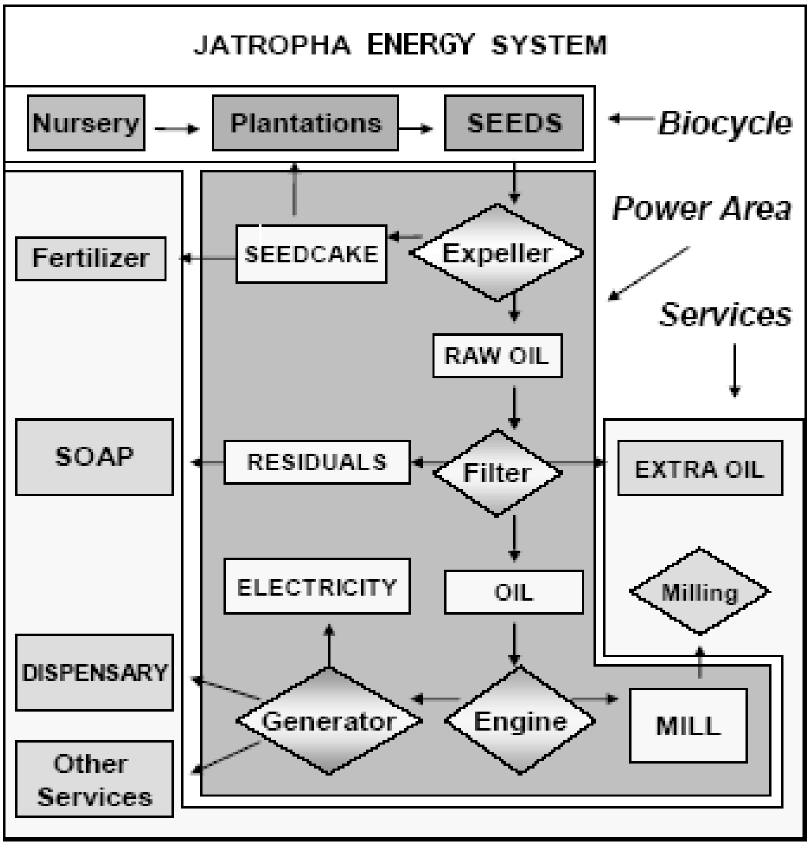

Figure 5. Flow Diagram of the Jatropha Energy System (Chachage, 2003)

As shown in Figure 5, the estimated production cost of Jatropha oil can be sensitively lower than conventional diesel for many rural communities in sub-Saharan Africa. Low labour and investment costs make the JES a low-risk system, which allows communities to save money on fuel. As diesel or gasoline tends to be a big cost factor in local village life, with those fuels making up even the biggest cost in marketing agricultural produce, the JES offers an attractive opportunity to generate income (through the sale of oil) and savings (on operating costs of local production processes). When a cooperative approach is taken, these extra-savings can be used to lower milling charges, to support social services or to be invested in extensions of the system. Once a community has gained experience with the system and acquired a routine of replicating it, it may even begin to think of entering wider regional markets as a biodiesel feedstock producer.

A careful micro-economic and technical analysis showed that the JES could remediate the problem significantly, even though the implementation of the system posed certain legal, managerial and ownership issues. The modularity of the JES makes it a flexible energy solution though, capable of accommodating these issues. The basic intention was to see whether a cooperative organization could adopt the entire system and operate the nursery, the plantation, the milling service and the generator, and to sell the much-needed electricity to the dispensary ("bottom-up" approach). But as the dispensary is State-run, doubts arose over whether such a cooperative organization is legally allowed to sell electricity to the state. Another option consisted of joining two para-statal enterprises, whereby one would own and manage a nursery, a plantation on a government or communal plot, a mill (thus offering a number of jobs to local people), and a generator, while the other para-statal (the dispensary) would buy electricity from the first one.

2.10 Biodiesel from Jatropha: Process Steps

The estimated production cost of jatropha oil as a biodiesel can be sensitively lower than conventional diesel for many rural communities in sub-Saharan Africa. The process steps are as enumerated below.

2.10.1 *Preparation of Seeds*

In a report by Biswas *et al.* (2006) it was reported that ripe fruits are plucked from the trees and the seeds are sun dried. They are decorticated manually or by decorticator. To prepare the seeds for oil extraction, they should be solar heated for several hours or roasted for 10 minutes. The seeds should not be overheated. The process breaks down the cells containing the oil and eases the oil flow. The heat also liquefies the oil, which improves the extraction process. Oil can be extracted from the seeds by heat, solvents or by pressure. Extraction by heat is not used commercially for vegetable oils. The oil from Jatropha seeds can be extracted by three different methods. These are mechanical extraction using a screw press, solvent extraction and an intermittent extraction technique namely soxhlet extraction.

2.10.2 *Purification of Jatropha Oil*

The oil extracted as above can be purified by the following means:

I. **Sedimentation** This is the easiest way to get clear oil, but it takes about a week until the sediment is reduced to 20 - 25 % of the raw oil volume.

II. **Boiling with water** The purification process can be accelerated tremendously by boiling the oil with about 20 % of water. The boiling should continue until the water has completely evaporated (no bubbles of water vapour anymore). Boiling for a few hours renders the oil clear.

III. **Filtration** Filtration of raw oil is a very slow process and has no advantage in respect of sedimentation.

2.10.3 *Processing of Jatropha Oil*

The quality of feed vegetable oil particularly FFA content plays an important role in identifying the suitable technology. The important factors to be considered for a biodiesel production plant include:

i. Processability of a variety of vegetable oils without or with minimum modifications
ii. Processability of high free fatty acid (FFA) containing oils/feedstocks
iii. Ability to process raw both expelled and refined oil. Process should be environmentally friendly with almost zero effluent

Certain difficulties are experienced in IC engines while using Straight Vegetable Oil (SVO) or chemically unmodified vegetable oils. One major problem is the higher viscosity of vegetable oils. The triglycerides as present in vegetable oil are mostly associated with their high viscosities, low volatilities and polyunsaturated character. Thus property modifications by trans-esterification are required to impart properties similar to petroleum diesel to the vegetable oil. The selection of appropriate technology for production of biodiesel calls for careful selection of processing steps, catalyst and downstream process integration. Various methods for processing of oil into biodiesel are as follows:

i. Pyrolysis
ii. Micro-emulsification
iii. Transesterification

2.10.4 *Pyrolysis*

Pyrolysis refers to a chemical change caused by application of thermal energy in the absence of air or nitrogen. The liquid fractions of the thermally decomposed vegetable oil are likely to approach diesel fuels. The pyrolyzate has lower viscosity, flash and pour points than diesel fuel but equivalent calorific values. The acetane number of the pyrolyzate is lower. The pyrolysed vegetable oils contain acceptable amounts of sulphur, water and sediment with acceptable copper corrosion values but unacceptable ash, carbon residue and pour point.

2.10.5 *Micro-emulsification*

The formation of micro-emulsions (co-solvency) is a potential solution for reducing the viscosity of vegetable oil. Micro-emulsions are defined as transparent, thermodynamically stable colloidal dispersions. A micro-emulsion can be made of vegetable oils with an ester and dispersant (co-solvent), or of vegetable oils, an alcohol and a surfactant and acetane improver, with or without diesel fuels. Water (from aqueous ethanol) may also be present in order to use lower-proof ethanol, thus increasing water tolerance of the micro-emulsions.

2.10.6 *Transesterification*

The process of converting the raw vegetable oil into biodiesel, which is fatty acid alkyl ester, is termed as transesterification. There are three basic routes to biodiesel production from biolipids (biological oils and fats):

i. Base catalyzed transesterification of the biolipid carried out under atmospheric pressure and at temperature of 60-70 °C,

ii. Direct acid catalyzed transesterification of the biolipid

iii. Conversion of the biolipid to its fatty acids and then to biodiesel

The processing steps for the most commonly used method namely base catalyzed transesterification of the biolipid would be as follows:

i. Exact quantity of potassium hydroxide required as determined by titration is thoroughly mixed in methanol till it dissolves completely to result in potassium methoxide.

ii. Jatropha oil is heated, if required (e.g. during winter), and mixed in the potassium methoxide with agitator running.

iii. It is then allowed to settle and glycerine is removed from the bottom.

iv. Biodiesel fraction is then washed and dried.

v. It is then checked for quality.

Transesterification, also called alcoholysis, is the displacement of alcohol from an ester by another alcohol in a process similar to hydrolysis. Methanol is most commonly used for the purpose since it is the cheapest alcohol available. Ethanol and higher alcohols such as isopropanol, butanol etc. can also be used for esterification. Using higher molecular weight alcohols improves the cold flow properties of biodiesel but reduces the efficiency of transesterification process.

Methods commonly used for producing biodiesel are batch and continuous processes. In general, smaller capacity plants, in particular with variable feedstock quality justifies the use of batch systems, as was shown in Figure 5 (p. 21). Continuous systems generally require larger capacities to justify larger staffing needs and also require uniform feedstock quality. The transesterification works well when the input oil is of high quality. However, quite often low quality oils are used as raw materials for biodiesel preparation. In cases where FFA content of the oil is above 1%, difficulties arise due to the formation of soap, which promotes emulsification during the water washing stage. If the FFA content is above 2%, the process becomes unworkable. The factors affecting the transesterification process are i) oil temp. (ii) reaction temp. (iii) ratio of alcohol to oil. (iv) catalyst type and concentration. (v) intensity of mixing. (vi) purity of reactants.

2.11 Storage of Biodiesel: Problems Encountered

The efficient storage of biodiesel resources can provide energy security to the country. Adequate data are not available for long-term storage of biodiesel and blends. Based on the experience, biodiesel can be stored up to a maximum of six months. A mild solvent, biodiesel tends to dissolve sediments normally encountered in old diesel storage tanks. Brass, teflon, lead, tin, copper, zinc etc. oxidize biodiesel and create sediments. The existing storage facilities and infrastructure for petrol and diesel can be used for the biodiesel with minor alterations. For biodiesel storage, shelf life and how it might break down under extreme conditions assume importance. The following merit attention for storage of biodiesel:

i. Biodiesel has poor oxidation stability and use of oxidation stability additives is necessary to address this problem.

ii. Low temperature can cause biodiesel to gel but on warming it liquefies quickly. Thus, insulation/jacketing of storage tanks and pipelines would need to be done at the low temperature zones.

iii. To avoid oxidation and sedimentation of tanks with biodiesel, storage tanks made of aluminium, steel etc. are recommended for usage.

2.12 Biodiesel Production

Expellers or continuous screw presses are used throughout the world for the extraction of oil from copra, palm kernels, peanuts, cotton seeds, flaxseed and almost every other variety of seed; wherever there is a large enough seed supply to justify a continuous operation. An expeller can exert much greater pressure on the seed cake than a hydraulic press can. This increased pressure permits the recovery of a larger proportion of the oil, about 3-4% of the oil is left in the cake with an expeller, compared to 4-6% with a hydraulic press. The expeller is an essential part of almost all modern oil seed extraction plants. It is used both by itself and as a pre-press before solvent extraction. Expellers vary in size from machines that process 100 pounds of seed per hour, to machines that process 10 or more tons of seed per hour. Different types of oil expellers for Jatropha seeds are built in many countries.

Biodiesel technology providers worldwide are Lurgi PSI, Superior Process Technologies, Biodiesel Industries, Cimbria Sket ñ Bratney, Crown Iron Works, Renewable Energy Group etc. The following types of small scale extractors are being used worldwide. Screw-cage type Sayari expeller was developed by FAKT Consulting Engineers, Dietz, Metzler, Zarrate for use in Nepal. It was fabricated using the iron sheets instead of cast iron to limit the weight of the parts to 40 kgs. The processing capacity is 70 kg of Jatropha seeds/hour, the residual oil content in the press cake is 10-12%. The price is around US$4000 including the motor and base frame. Oil extractor was provided with hard screws and cones in a modular assembled form in one shaft. The advantage of this expeller is preheating of seed is not required.

Komet oil expellers manufactured in Germany, feature a special cold pressing system with a single conveying screw to squeeze the oils from various seeds. Virtually all oil-bearing seeds, nuts and kernels can be pressed with the standard equipment without adjusting the screws or oil outlet holes. The vegetable oil produced needs no refining, bleaching or deodorizing. Generally, any sediment in the oil will settle to the bottom of the collecting vessel after approximately 24 hours and form a hard cake.

2.13 Jatropha Activities in Ghana

According to a report by KITE (2007), Jatropha activities in Ghana can be categorized into three main activity groups – cultivation, production/processing and usage. Almost all the ongoing efforts at developing biodiesel are driven by private sector investors and non-governmental organisations and supported, in some cases, by donor agencies. The cultivation of Jatropha in Ghana had till recently been primarily private sector-driven involving individual farmers and/or farmer cooperatives. It is estimated that a total of 1,534 hectares of Jatropha plant have been placed under cultivation. Some of the stake holders in the cultivation of the plant are: Biodiesel One Ghana Limited (B1 Ghana Ltd), ADRA/UNDP in collaboration with Anuanom Industrial Project Ltd., AngloGold Ashanti Ltd, GRESDA-GH/GRATIS and Valley View University.

2.13.1 *Adventist Development Relief Agency (ADRA)/UNDP and Anuanom Industrial Project Ltd*

The Adventist Development Relief Agency (ADRA) in collaboration with Anuanom Industrial Bio-Products (AIBP) Ltd has the largest plantation of Jatropha in Ghana. The project targeted the cultivation of 1,600 hectares of Jatropha plantations in Ghana out of which 800 hectares had been established by October 2003 in five regions in Ghana – Central, Eastern, Volta, Brong-Ahafo, and Greater Accra regions. The project was sponsored by UNDP co-financing it with 50.000 USD by Global Environment Facility (GEF) and ADRA. A highly productive variety bearing nuts with oil content of 60-67% is raised here. The seeds are delivered to farmers who wanted to participate in the production of *Jatropha curcas* L. Since 2000, an incentive program promotes the cultivation of *Jatropha curcas*. The Ministry of Agriculture supports with personnel who promote *Jatropha curcas* L. in meetings with rural Local Assemblies giving information and training around the cultivation of the plant.

According to ADRA, the initiative resulted in the cultivation of 3,000 acres of Jatropha plantations in 2002, the first year of the project. However due to a number of problems, which included poor quality of seeds, late planting and poor rainfall pattern, a significant proportion of the plantations failed. Consequently, the project activities in 2003 focused mainly on the rehabilitation of the existing plantations, which led to the successful rehabilitation of 1,800 acres. In summary the ADRA/UNDP initiative has so far resulted in the establishment of 1,800 acres of Jatropha plantation by over 1200 farmers in 93 communities scattered across 5 regions in Ghana. The cultivation of new plantation has however been on hold since late 2005 due to several teething problems some of which are: frequent seed shortage caused by AIBP's inability to supply seeds regularly and in the right quantities demanded, pest infestation, lack of marketing outlets for their seeds and lack of financial resources to plant on a commercial basis (KITE, 2007).

2.13.2 *Biodiesel One, Ghana Limited*

Biodiesel One Ghana Limited, which is a private company, is also involved in the cultivation of Jatropha. The company has secured 12,000 hectares of land in the Brong-Ahafo region for feedstock production. Biodiesel One initially cultivated 700 hectares of jatropha plants at Kwame Danso, near Atebubu in the Brong-Ahafo region. However, virtually the entire plantation, which had a tree density of 1,400 trees per hectare, has been destroyed by fire. Only 5 acres of the young plantation survived the fire implying a huge loss to the company. The company has established a subsidiary company called Precisions Farms and Oils Limited that handles the cultivation segment of its business. Currently, the subsidiary company is working closely with the National Youth Employment Programme (NYEP) and the district assemblies to engage the youth in the cultivation.

2.13.3 *AngloGold Ashanti Goldfields Limited/Obuasi Municipal Assembly Initiative*

Anglogold Ashanti and the Obuasi Municipal Assembly, has put in place measures to cultivate 20,000 hectares of jatropha plantation at the Jimiso Krakraba and the Addase communities in the Ashanti region as well as on the company's degraded mining lands. The project is aimed at creating jobs for the youth, especially those involved in illegal mining activities and restoring the forest cover of degraded mining lands. It is intended that each interested individual will be given up to 3 hectares of land for cultivation. Planting materials (seedlings) will be supplied by AngloGold Ashanti, who also undertakes to buy all the seeds harvested. AngloGold Ashanti intends to produce over 10 million seedlings over the next five years and currently has over a million seedlings in stock, ready to be sold to individuals who want to buy at the price of ¢1,000/per 4-month old seedling. Anglogold Ashanti has cultivated 40 hectares of Jatropha plants on degraded lands in a community called Sansu under its Environmental Programme and has plans to offer up to 20,000 hectares of land to private individuals and organizations interested in large scale cultivation of Jatropha.

2.13.4 *The Valley View University/AIBP Initiative*

This collaborative research project is between the Valley View University at Oyibi area in Accra and the AIBP with the view of gaining deeper understanding in the cultivation of the Jatropha plant. The findings obtained from the research were expected to be incorporated into the curriculum of the then newly established agriculture department at the university. The project has been ongoing for the past four years. AIBP provided the seeds for cultivation of an initial 5 acres of Jatropha plants in November 2002. The university has currently increased the total acreage under cultivation to about 20 acres. Harvested seeds are bagged and sold to AIBP. The original spacing specified by AIBP was 3 x 3 metres, which would have resulted in approximately 450 plants per acre. The University however used a planting width of approximately 1.7 metres, thereby increasing the plants per acre to approximately

870. According to a representative of the University, the reason for increasing the plants per acre was to provide some materials that could be cut for propagation within two months after planting, reverting thereafter to the recommended spacing of 3 x 3 metre. The Valley View University encountered some problems, which they said were, caused by intercropping and the adoption of tighter planting width. Browning of leaves, believed to have been caused by intercropping, was a notable problem identified.

2.13.5 *GRATIS Foundation/GRESDA-GH*

The GRESDA Ghana project in collaboration with the GRATIS Foundation, Gbimsi women's group and other institutions established the initial 10-acre plantation that supplied the project with Jatropha seeds. The first biofuel extraction project in rural communities operated by illiterate rural women was implemented at Gbimsi in the Northern Region of Ghana under the GRESDA-GH project supported by UNIFEM, GRATIS Foundation and UNDP-GEF.

2.13.6 *The Ghana Chamber of Mines*

The Alternative Livelihood Projects (ALP) by the Ghana Chamber of Mines is to cultivate Jatropha on degraded mining lands. The Chamber of Mines has since 2006 entered into a collaboration agreement with Bio Diesel One Ltd from Norway, for a Jatropha cultivation and refining programme in the catchments areas of mines. Bio Diesel One Ltd. intends to plant a total of 1.7 million Jatropha trees, capable of producing more than 2.5 million litres of Jatropha crude oil for biodiesel production.

Two Jatropha species will be planted; one local specie and another high yielding Indian breed. Biodiesel One Ltd. farm operations are mechanised involving tractors, ploughs, harrows and water irrigation equipment. All the tractors run on neutral biodiesel (B100); 5,000 litres of the biodiesel were imported alongside the tractors and this is expected to be more than enough to cultivate the 850 hectares of land. In addition to the above mentioned Jatropha activities in Ghana, there are some that are still in the pipeline. Some of these are:

2.13.7 *Jatropha Energy Development for Rural Communities in Ghana Project*

The first biofuel extraction project in rural communities operated by rural women was implemented at Gbimsi in the Northern Region of Ghana under the GRESDA-GH project supported by UNIFEM, GRATIS Foundation and UNDP-GEF. This was followed by another one implemented by the Technology Consultancy Centre (TCC) of the KNUST in collaboration with Cambridge University, United Kingdom which has been on-going under the theme "Jatropha Energy Development for Rural Communities in Ghana" Project, under which a 22-acre land at Biemso 1 community in the Ahafo-Ano South District of the Ashanti Region has been acquired for Jatropha plantation and a bio-diesel processing plant.

2.13.8 Aburaman Biofuels Company Limited (ABC Ltd)

Aburaman Bio-fuels Company Limited (ABC Ltd) in the central region has since 2006 established plants to cultivate Jatropha for biodiesel production. The company also aims within the same period to develop its own 1,000-acre Jatropha plantations to produce about 2,000 tons of Jatropha seed. The company in addition plans to build and operate a factory capable of processing 10 tons of *Jatropha Curcas* seed per 8-hour per day to produce 3 tons per day of *Jatropha Curcas* oil (close to 1,000 tons per annum).

2.14 Botanical Origin of Shea Butter

The shea tree, *Butyrospermum parkii* (G. Don) Kotschy, called Karite in French, Kra-Nku (Twi), Nkudua (Fanti), Kanku (Ashanti), Adanpo (Brong), Ngu (Nzima), Gue (Bawle), Nku (Ga), Yokuti (Ewe), Tango (Moshie) and Kadainya (Hausa), belong to the family Sapotaceae. Atta (1978) reported that *Butyrospermum parkii* has three main varieties namely, *Mangifolium, poissoni* and *niloticum.* He further classified them into sub-varieties, such as, *cuneata, serotina* and *parviflora* under the mangifolium variety, and *ferruginea* and *flocosa* under the *poissoni* variety. No sub-variety was detected for niloticum. The study (Atta, 1978) further reported that only one variety, *poissoni,* occurs in Ghana.

The shea tree grows spontaneously in the wooded savannah areas of West Africa namely Ghana, Mali and Burkina Faso. Associated cultures underneath can be made but trials to cultivate shea trees have always failed. The tree is stout, can grow up to 20 metres high and its trunk can reach one metre in diameter, bearing leathery oval leaves (http://www.sheabutter.com, 2001). It produces its first fruit when it is about 25 years old and reaches its full production at the age of 40 or 50 years. Shea butter is obtained from the nuts of the Mangofolia tree and it is also called Karite butter or African butter. It is high in triglycerides and has 5% fatty acids, 8% unsaponifiables, and 7% waxy esters. The edible fruit contains one to three seeds surrounded by a thin brittle hull. The kernels are about 50% shea butter. One tree produces 15 to 20 kg of fresh fruit, which corresponds to 3 to 4 kg kernels and 4 kg of kernels makes 1 kg of shea butter.

2.15 Traditional Processing of Shea Butter

The traditional methods of processing of shea butter have been studied by various researchers (Bienayme *et al*., 1956; Ruyssen, 1957; Bagot, 1958; Hill, 1959; Mital and Dove, 1971). Two main methods were identified as being practised in Ghana, being,

a. The Dagombas and Mamprussi method.

b. The Nanumba and Kokombas method.

In the Dagombas and Mamprussi method, the fruits are boiled for about 5 hours and sun-dried until the nuts are believed to be dry. The shells are removed by light pounding in a mortar and the broken shells separated from the kernels by winnowing, that is, the broken shells being the lighter weight are blown off by the wind whilst the heavy kernels are collected in a basket placed underneath. The kernels at this stage may be stored for future processing. When processing begins, the kernels are roasted in an open pan till they are fairly dry. The kernels are then placed in a mortar and pounded till sufficient oil has exuded to permit stirring into a sticky mass. The mass is then warmed by fire and then transferred into the mortar to be pounded again until its consistency resembles chocolate. It is then transferred to grounding stones and ground further till the fat begins to flow. The mass is then mixed with quantities of water and sand and stirred by hand until the fat settles at the top. The settled fat is skimmed off into a separate bowl. In order to generate more fat the remaining mass is boiled and allowed to cool. More fat settles on top which is again skimmed off. The residue which comprises sand and the cake is thrown away.

With the Nanumba and Kokumbas method, fresh fruits collected are dried in the sun for periods varying from 10-20 days. The nuts are broken on stones and the kernels picked by hand. They are then taken to a kiln and placed over a slow fire for about 10 days. The dark roasted kernels are pounded to obtain a thick black mass. This is then mixed with hot water and boiled with stirring. The released butter is skimmed off and cold water is then added to the residue to release more oil which is also skimmed off. Again the residue comprising mainly the cake is thrown away.

The main difference existing between the two methods lies in the preparation of the kernels. The fresh nuts are dried in the sun for about 20 days in one practice while nuts are boiled and dried in another. This method of preparation has a direct relationship to the browning of the kernel which is encountered in the processing. The greatest difference observed in the two samples was that kernels obtained from the Nanumbas are usually very mouldy as opposed to those from the Dagombas. The reason is due to the fact that the mesocarp of the fruit surrounding the nut is high in sugars and this turns to attract moulds and yeasts. In the process of boiling, the moulds are killed and the nuts remain clean after drying. Without boiling, the moulds are not completely eliminated during the subsequent drying especially as drying takes up to 20 days.

Within the last 20 years however, the increased use of corn mills in the local small-scale industries have helped to eliminate some of the stages, for example grinding the kernels on stones. The traditional method of the Dagombas which is more popularly used because it produces better quality fat is outlined in Figure 6. The scheme is further explained as follows;

Stage I. Collection of Fruits and Nuts

Collection of fruits and nuts is usually done by families comprising mainly women and children. Collection begins at early dawn and proceeds until about mid-day, when the heat of the sun compels workers to retire. Collectors have to move from one tree to the other gathering whatever is beneath and it has been estimated that collectors do not travel beyond a two mile radius from their base. The shea tree usually sheds its fruits in the middle of May and continues for about 90 days. This is the period in which collection of nuts for the whole years consumption is organized. The limitation is due to problems of transportation of the load since all the transportation is presently done on foot by head loads. Other factors which have been recognized by the natives as limiting the radius of collection includes,

a. The presence of wild animals especially baboons and monkeys.

These animals harass the women and so the women prefer to operate fairly near their villages.

b. Artificial territorial boundaries.

It is recognised that the shea tree of the north is common property but nevertheless each hamlet or settlement thus protect an undefined area of land around the settlement. Consequently each potential harvester is limited to only a specific area of collection. Since not all the inhabitants are involved with shell procurement, the total harvested crop turns to be lower than could have been obtained if there were no boundaries for exploration. These factors account for a great deal of the poor harvest obtained each year.

I Collection of shea fruit and nut from farms

II Boiling of fruits to soften and remove mesocarp

III Drying in sun or kilns of boiled nuts

IV Deshelling by cracking on stones

V Storage of kernels for sale and processing

VI Roasting of kernels in open pan

VII Milling of roasted kernels

VIII Addition of water and beating to remove colour and generate fat

IX Boiling of crude fat to expel traces of water

X Gradual cooling of molten fat to form uniform

Figure 6. A Scheme for the Traditional Processing of Shea Butter (Dagomba Method)

Source: From Author’s Field Work

Stages II and III: Removal of Mesocarp

Stages II to III are concerned with the removal of the sweet mesocarp which then exposes the nuts. Much of the sweet mesocarp is eaten but boiling and subsequent drying also helps in the removal of the remaining adhering mesocarp from the nuts. It has been observed that the method in which the collected fruits are left for long periods to dry causes much deterioration. Laboratory test show that *Aspergillus*, *Rhizopus* and *Penicillium* species are the ones that most proliferate and permeate the shells, thus infecting the kernels. Thus, before the nuts are cracked and placed in kilns most of the kernels are already brown. Even though the kernels are already brown, the type of drying equipment used, that is, the kiln produces the same effect as roasting which also contributes to further darkening of the kernels. In addition to this, the process of fat extraction starts with the roasting of the kernels which also contributes to the darkening of the kernels.

Stage IV: Shelling

The shelling process also causes a lot of damage to the kernels and examination of about 500 kernels revealed that about 80 % have been visibly bruised. It is still possible that the remaining 20 % had bruises which could not be detected.

Stages V to VII: Preparation of Raw Material for Fat Extraction

The shelled kernels are generally roasted in open pans till they are fairly dry and milled into paste. This process is fairly similar to the heat treatment of raw materials in a conventional oil mill and it is designed;

a. To disrupt the cell structure thus making extraction easier,

b. To reduce the moisture content.

The latter effect however does not apply to the traditional process since water is added at the latter stages of the process.

Stage VIII: Kneading

From the work of Halff (1954) in Sudan, the process of kneading comprises the following stages:

a. Mixing the paste with water
b. Beating the paste with a palm of the hand
c. Adding further small quantities of the water
d. Gathering the floating fat which could take about five hours for a woman working on a 13 kg batch of dry roasted kernels.

Upon careful examination, it has been observed that the process of kneading which is the most important process in the flow sheet serve two main purposes:

a. To release the fat from the ground mass
b. To remove as much of the brown colour as possible from the brown mass and produce a fairly clean fat.

It has been observed that the efficiency of the traditional process which is limiting *per se* will be lower still if kneading were not done by experienced operators. It is also during the kneading process that the cake is lost. The kneading process is therefore a very vital unit process in the method especially with respect to colour removal and use of meal.

Stage IX: Removal of Excess Water

This process inevitably takes place in order to reduce the moisture levels of extracted fat. The process usually takes 8-10 hours of slow heating of the extracted butter.

Stage X: Recrystallization

It involves the gradual cooling with stirring of the molten fat till it assumes a smooth pasty consistency.

2.16 Shea Butter Quality for Consumption and Industrial Use

The fundamental composition determined by identity characteristics such as iodine value, saponification value and refractive index does not change with the method of extraction of the fat, i.e. whether by screw press, solvent extraction or by the traditional method provided the same species of plant material is used. The quality characteristics however, may change due to the method of processing. Among the quality characteristics, the most important for consideration from the point of view of human consumption and industrial use are;

i. Colour

ii. Free fatty acid

iii. Peroxide value

iv. Impurities

The traditionally manufactured fat exhibit some amount of plasticity since it has fairly high levels of moisture (1%) with which it forms an emulsion. Table 2 presented below shows a comparison of the quality characteristics of a traditionally manufactured shea butter and a laboratory screw press sample.

Table 2. A Comparison of the Quality Characteristics of Traditionally Produced and Laboratory Screw Pressed Sample of Shea Butter

Quality characteristics	**Traditional** **25 different samples**	**Laboratory** **10 samples**
Impurities (IUPAC, 1964)	1.20 – 3.49	0.0 – 0.02
Peroxide value Acid (oleic)	2.15– 7.0	0.6 – 1.0
Colours (subjective)	dirty greyish when fat solidifies	pure white and attractive colour when fat solidifies

Source: Adomako (1982)

From the point of view of edibility the laboratory screw press sample present an ideal quality of virgin oil. The free fatty acid content is low, indicating minimum lipolitic activity; the peroxide value is low also indicating a lower oxidation state of the fat. The level of impurities is an indication of the level of contamination of the fat with fine particles of the solids phase that is the cake. In the laboratory sample, the lower value is due to a good filtration process after extraction. It was observed that in the traditional system, there is no filtration and the separation of the oil phase from the non fatty phase is by skimming or decantation. Though the colour difference between the two samples was assessed subjectively, the poor colour of the traditionally processed sample is an indication of poor quality. The dark greyish colour may be associated with both impurities and wash water. This state renders the fat unattractive for purposes of human consumption.

2.17 Characteristics of Shea Butter

Shea fat is obtained from the kernels of the shea tree, *Butyrospermum parkii* and *Vitellaria paradoxa* in Ghana. The tree being a member of the Sapotaceae family grows well in West and Central Africa (Salunkhe and Desai, 1986; Atta, 1978). The fat, estimated to form 40-55% of the kernel has the characteristics and fatty acid composition as indicated in Tables 3 and 4 below (Tano-Debrah and Ohta, 1994; Salunkhe and Desai, 1986).

Table 3. Product Characteristics of Shea Butter

Characteristic	Mean Value
Iodine Value	58.5
Saponification Value	180.4
Unsaponifiable matter	7.5
Melting range (°C)	34-36

Source : Tano-Debrah and Ohta (1994)

Table 4. Fatty Acid Composition of Shea Butter

Fatty acid	Mean Value
Palmitic	3.6
Stearic	44.4
Oleic	42.4
Linoleic	5.9

Source : Salunkhe and Desai (1986)

According to the Ghana Standards Board, standards for vegetable oils and fats should conform to the stipulated standards (Ghana Standards Board, 1970). Crude shea butter shall be the oil obtained by expression or by solvent extraction or by traditional methods from whole, sound and clean kernel of *Butyrospermum parkii* nuts. It shall be free from admixture with other oil or fat and shall conform to the specifications as stated in Tables 5 and 6.

Table 5. Standard Specifications for Crude Shea Butter in Ghana

Index	Mean value
Refractive index at 40 ^{o}Ċ	1.4619-1.4670
Iodine value	54.0-63.0
Saponification value	289-299
Unsaponifiable matter	2-3%
Free fatty acid	not more 5%.

Source: Ghana Standards Board (1970)

2.18 Quality Specifications for Shea Kernel and Shea Butter

Among the indications of quality in the pricing mechanism are the fat content, moisture content and the free fatty acid (FFA) content of the kernel or butter. The basis for a permissible FFA is fixed at 7% with a maximum tolerable level at 10% on the world market. With the specification of shea butter quality, the Ghana Standards Board Quality Specification Committee stresses on the maximum impurity level as well as the oil content of the butter to be 0.01% and 99.4 % respectively to ensure maximum quality of the final product (Ghana Standards Board, 1970). These export quality specifications are as shown in Tables 6 and 7 below.

Table 6. Export Quality Specification for Shea Kernel

Characteristic	**Maximum value (%)**
Moisture	10
Fat/Oil	45
Free Fatty Acids	8
Ad mixture	1

Source: Ghana Standards Board (1970)

Table 7. Export Quality Specification for Shea Butter

Characteristic	Content
Moisture	0.51%
Free Fatty Acids	5% (maximum - crude)
Impurities	0.01%
Iodine Value	32%
Colour	0.7 red, 3 yellow
Oil	99.4%

Source: Ghana Standards Board (1970)

There are nine principal functions in the shea sub-sector. These functions are divided into two segments in relation to the two commodities, shea kernel and shea butter, which are produced from the shea nut. The major functions for production and marketing of shea kernel are research, input supply, picking, wholesaling, and retailing. The next range of functions required to obtain and market shea butter are processing, wholesaling, retail and further processing to obtain refined shea butter.

The picker-processors, pickers, kernel traders, processors and shea butter traders can each be further categorized into two segments in relation to their methods of product distribution. Each distributes its product either through retail or wholesale. The significance of this categorization is shown by the fact that the participants engaged in the retail trade dominate the domestic market both for kernels and butter while the wholesalers are more prominent on the export markets.

2.19 Physical and Chemical Properties of Shea butter

The physical and chemical properties of crude shea butter extracted and analysed at the Cocoa Research Institute of Ghana by Adomako (1982) had observed properties as indicated in Table 8.

Table 8. Physical and Chemical Properties of Crude Shea Butter

Characteristic	Content
Ash content	3.2
Melting point	38.0-39.5°C
Slip point	36.7-37.4
Iodine number	64.2
Acid number	13.4
Free fatty acid (as oleic)	6.8%
Saponification number	179.6-190.0
Unsaponifiable matter	7.3-9.0
Fat Content	52.1%
Solidification point	26.5-30.0°C
Degree of unsaturation	0.59

Source: Adomako (1982)

Research studies conducted on the physical and chemical properties of refined shea butter at the Cocoa Processing Company of Ghana are as shown on Table 9 below.

Table 9. Physical and Chemical Properties of Refined Shea Butter

Characteristic	Content
Free fatty acid as oleic	0.51
Saponification number	178.55
Unsaponifiable number	5.54
Acid value	1.02
Ash	0.07%
Slip point	37.4
Solidification point	26°C
Specific gravity	0.89

Source: Cocoa Processing Company (2001)

Shea butter has the aspect of a soft paste or melted fat, with a greenish, yellowish or whitish colour and a more or less characteristic pleasant odour. After being industrially refined, the product looses this odour almost completely. Crude shea butter has natural antioxidant properties due to its content in tocopherols. The tocopherols, which are natural antioxidants, are known to inhibit oxidation by being preferentially oxidized. This preferential oxidation appears to occur only during the induction phase and antioxidants have no effect after the induction period (Kirk and Sawyer, 1991). When the fat is subjected to atmospheric oxygen at high temperatures, objectionable flavours and taste develop due to induction and rapid peroxide formation. First, the peroxide radicals accumulate slowly and hydroperoxides are built up from the reactions of the peroxides and other molecules having active methylene groups. The hydroperoxides decompose and give rise to carbonyl compounds of aldehydes and ketones, which are responsible for the objectionable flavour and taste (Mital and Dove, 1971).

2.20 Importance and Traditional Uses of Shea Butter

2.20.1 *Importance of Shea Butter*

The importance of shea butter as a raw material for the small-scale industry in Ghana cannot be over emphasized. In northern Ghana shea butter is the fat commonly used for food, cream and soap production. According to GEPC (2000) the mean consumption of shea fat in the upper part of Ghana was about 18g/head/day. Information collected from the Export Promotion Council further indicated that the cumulative export of shea butter amounted to 32,000 tons in 1999, which increased to 39,000 metric tonnes in 2000, indicating its importance as a foreign exchange earner for the country (GEPC, 2000). It is mainly exported to Britain and France where it is used in the formulation of cocoa butter substitutes, and in the food industry for the production of chocolate and margarine. Currently, the production of shea butter serves as an income generation venture for most women in the northern regions of Ghana.

2.20.2 *Traditional Uses of Shea Butter*

Shea butter is an important source of edible fat for the processing of a wide variety of foods for a large segment of Ghanaians in the northern regions, especially the Mamprussis, Dagombas and Nanumbas. Apart from its use for food processing, shea butter has many traditional uses which include the following;

i. It is massaged on the body after washing to relax the muscles and soften the skin, especially during the dry season.

ii. It is also used to treat sprains, wounds and colds and it can be used as an after-shave and a hair balm, as it fixes dry, brittle hair.

iii. It is sometimes applied on the umbilical cord of new born babies to facilitate its healing.

iv. Shea butter makes the fibres of traditional drumhead suppler and protects them from drying and cracking. The fibres absorb the oils and become water repellent, so their tuning is much less influenced by temperature and humidity changes. It protects the drumhead against exposure to the sun.

v. It has soothing, moisturizing and protecting effects on human hair. Due to the presence of a sizeable quantity of unsaponifiable fats, its content in vitamins and other active elements it adds other more precise activities to these general properties.

vi. It displays a protecting role against UV rays because of its content in cinnamic acid and can thus be incorporated in solar products. The natural latex contained in shea butter would moreover prevent certain sun allergies.

vii. Shea butter has an activity on cell regeneration and capillary circulation. This favours the healing of small wounds, skin cracks and crevices, and skin ulcers. In the cosmetic field, this property is an asset against skin ageing as it has restructuring effects on the epidermis of human skin

viii. It has an anti-elastase characteristic, which makes it a good active ingredient against stretch marks. It can also be used to treat rheumatism and aching muscles, and to ease colds because it decongests nasal mucous tissues.

ix. Shea butter softens the lips and gives them a protective film against the cold and harmattan, and it totally wipes out diaper rash.

x. The regular use of shea butter in addition to sunscreen products, before and after sun exposition, leaves people with tanned skin and avoids peeling (Atta, 1978; Salunkhe and Desai, 1986; Tano-Debrah 1997; http://www.sheabutter.com, 2001).

2.21 Chemistry of Edible Fats

Fats are a heterogeneous group of naturally occurring substances which are insoluble in water but soluble in organic solvents such as ether, chloroform, benzene and acetone (Aurand and Woods, 1973). Edible fats are complex mixtures of triglycerides and small amounts of other substances occurring naturally or are derived through processing and storage of the fats. In general, edible fats and oils contain the following; triglycerides, diglycerides, monoglycerides, fatty acids, phospholipids, sterols, fat-soluble vitamins, pigments, hydrocarbons, oxidative products, trace elements, trace metals and water (Fennema, 1976).

The natural fats are made up mostly of mixed triglycerides with only trace amounts of the mono- and diglycerides and little or no free fatty acids. In contrast, processed fats may contain up to 20 % of the mono- and diglycerides. The associated substances are important, for example, the fat-soluble vitamins, sterols, and phospholipids are of nutritional importance; the free fatty acids are an index of the degree of hydrolysis of a triglyceride; the presence of peroxides, aldehydes and ketones are indicative of the amounts of oxidative deterioration that has taken place in the fat (Aurand and Woods, 1973). Furthermore, certain sterols, phospholipids, carotenoid pigments, metallic impurities may contribute to the oxidative deterioration of the fat. Thus, it is necessary to understand the composition and structure of lipids in order to know their role in the biological chemistry of foods.

2.21.1 *Chemical Stability of Edible Fats*

Stability refers to the capability of a fat, oil, or fatty food to maintain a fresh taste and odour during storage and use. It is related to composition of the fat moiety, the nature and degree of stress on the system, the presence or absence of prooxidants or antioxidants, and the effectiveness of packaging. Fats with substantial unsaturation in the fatty acid are usually unstable or moderately unstable and foods containing them reflect this instability. Vegetable oils usually tend to be more stable than some of the animal fats, such as lards, even though the total unsaturation of the vegetable oils may be greater. This can occur because natural antioxidants are usually present in the vegetable oils (Fennema, 1976).

2.21.2 *Deterioration of Edible Fats*

Deterioration of edible fats, or rancidity, constitutes one of the most important technical problems of the food industries. All of the chemical reactions can be explained on the basis of the ester linkage and the nature of the fatty acids glycerides. Deterioration will occur through the hydrolysis of the ester linkage by lipases and moisture (hydrolytic rancidity), through the autooxidation of unsaturated fatty acids glycerides in atmospheric oxygen (oxidative rancidity), through the enzymatic oxidation of unsaturated fatty acid glycerides (lipoxidase rancidity), or the enzymatic oxidation of certain saturated fatty acid glycerides (ketonic rancidity) (Aurand and Woods, 1973).

2.22 Packaging Materials

2.22.1 *Packaging Defined*

Packaging was defined by Bram *et al*. (1983) as an industrial and marketing technique for containing, protecting, identifying and facilitating the sale and distribution of agricultural, industrial and consumer products. The packaging Institute International (Annon, 1988) defines packaging as the enclosure of products, items or packages in a wrapped pouch, bag, box, cup, tray, can, tube, bottle or other container form to perform one or more of the following functions: containment, protection and/or preservation, communications, and utility or performance. If the device or container performs one or more of these functions it is considered a package. The UK Institute of Packaging (Paine, 1977) also provides three definitions of packaging:

a. a coordinated system of preparing goods for transport, distribution, storage, retailing and end-use,

b. a means of ensuring safe delivery to the ultimate consumer in sound condition at minimum cost,

c. a techno-economic function aimed at minimizing costs of delivery while maximizing sales and hence profits.

It is important to distinguish between packaging as defined above, and packing which can be defined as the enclosing of an individual item or several items in a container, usually for shipping or delivery. Paine (1977) further explained that even though the definitions of packaging cover in essence the basic role and forms of packaging, it is necessary to elaborate on the functions of packaging and the environment where the package performs those functions.

2.22.2 *Functions of Packaging*

Robertson (1993) categorizes the functions of packaging under the following:

a. Containment: This is the basic function of packaging. With the exception of large, discrete products, all other products must be contained before they can be moved from one place to another. Without containment, pollution will be widespread. The containment function of packaging makes a huge contribution to protecting the environment from the myriad of products which are moved from one place to another on numerous occasions each day in a modern society. Faulty packaging or under-packaging results in a major pollution of the environment.

b. Protection: This is often regarded as the primary function of a package, to protect its contents from outside environmental effects, be there water, moisture vapour, gases, odours, micro-organisms, dust, shocks, vibrations, compressive forces, and to protect the environment from the product. This is especially important for those products such as toxic chemicals which may seriously damage the environment. However, for a majority of food products, the protection afforded by the package is an essential part of the preservation process.

c. Convenience: Packaging plays an important role in allowing products to be used conveniently. The ever changing societal behaviours and eating habits has led to a high demand for a wide variety of foods and drinks at out-door functions such as sports events, and increased leisure time, have created demand for greater convenience in household products; foods which are prepared and can be cooked or reheated in a very short time, preferably without removing them from their primary package; dispensers for sauce or dressing which minimizes mess, etc.

d. Communication: A package must protect what it sells and sell what it protects (Judd *et al*., 1989). The modern methods of consumer marketing would fail were it not for the messages communicated by the package. The ability of a consumer to instantly recognize products through distinctive branding and labelling enables supermarkets to function on a self-service basis (Sacharow, 1982). As well, warehouses and distribution centers would become shambolic if secondary and tertiary packages lacked labels or carried incomplete details for communication in marketing.

2.22.3 *Availability of Packaging Materials in Ghana*

Packaging is an important factor in any retail environment and a key element in most marketing strategies. Consumers react immediately to package shapes, and are influenced by them when making buying decisions. Different product categories are often easy to recognize by their characteristic form, e.g. chocolate boxes or milk cartons. On the other hand, a manufacturer of an exclusive product, such as jewellery or perfume may deliberately choose an unusual, eye-catching form. According to Robertson (1993), products must be contained before they can be moved from one place to another. Production of packaging material in Ghana is becoming increasingly important, after a post-independence period where most material had to be obtained from inefficient state-owned enterprises or imported, the private sector has developed its own resources. Among the available products are ceramics, calabash, different kinds of paper and carton products, wood products, glass products and various kinds of plastics (containers and films) (Table 10). The wood and paper or carton products appropriate for the products being looked into, such as laminated paper or carton as used in the tetra-pack packages are not in production in Ghana and are imported by some large scale entrepreneurs such as Astec Company Limited. Local production might be capital intensive and inappropriate for small-scale processors; so are the various kinds of metal cans. Calabash, polyethylene bags, metal cans and plastic containers will be evaluated in this study. Presently the role of packaging is being taken seriously in Ghana and UNIDO has teamed up with the Government of Ghana to set up a national body called the Packaging Cluster to be responsible for the growth of the packaging industry.

2.22.4 Ceramics

For the production of ceramics most of the raw materials of good quality are locally available. The material needed for glazing has to be imported. Ceramics are traditional packaging material in Ghana. The production process of simple ceramics is not complicated and can be handled by micro-enterprises in a rural setting. The introduction of gas bottles has eased the baking or firing process, which should take place at high temperatures and this has, consequently, reduced the prices of pottery products. Most of the ceramic products are handmade (without the use of a mould), which make them vary in sizes and shape. However, some manufacturers have started production on a larger scale (notably Saltpond Ceramics) and produce highly standardized pots and porcelain products. Moulds for pottery are not expensive, but only products with a specific shape can be made in a mould. Most kinds of jars and pots will have to be made by hand. The ceramic products are normally used to store water, honey, bitters etc.

2.22.5 *Glass Products*

About 95% of the raw materials needed for the manufacture of glass are available in Ghana (Ghana Standards Board, 1970). The main difficulty in glass production is the need for quite sophisticated machinery. The Aboso Glass Factory located in the Western Region of Ghana was operating with high losses until it was privatized. It now runs under the name "Tropical Glass", and it is the only producer of glass products in Ghana. Currently, its aim is to produce glass for the entire West African sub-region. Production as a private enterprise has been going on for almost ten years now and it produces only glass bottles. The introduction of tailor-made products, such as special bottles or jars, is difficult because of the high cost of the mould manufacture. Prices of mould depend on the amount and quality of steel needed, which varies with the type of mould and the kind of machinery for glass production. Local production of moulds is possible in Ghana with prices for a mould for a jar of 375 cc ranging between three hundred thousand Cedis (¢300,000.00) and Three million Cedis (¢3,000,000.00). Possibilities for the production of jars, for which the local demand seems very high and which are currently being imported on a relatively large scale mostly from the La Cote d'Ivoire and France deserve particular attention.

2.22.6 *Plastics*

Production of plastics in Ghana took off at the end of the 1980s and is dominated by Indian owned companies. Plastics are produced using conventional production methods. These include injection and blow molding. Owing to the lack of investment opportunities and the high interest rates only capital-intensive techniques are in use. The plastics produced in Ghana include:

- High Density Poly Ethylene (HDPE)
- Low Density Poly Ethylene (LDPE)
- Poly Propylene (PP)
- Poly Vinyl Chloride (PVC)
- PET Bottles

Other types such as High Impact Poly Styrene (HIPS) and Poly Ethylene Terephtalate (PET) are highly capital intensive (around half a million US dollars initial investment) and are currently available at a minimal volume. That is the case for the more advanced molding techniques like extrusion blow-molding and stretch blow-molding (techniques which line-up the molecules and makes the plastic resistant against acids). Co-extruded plastics are not in production. Moulds for the five types of plastics that are available can be produced in Ghana and will cost about ¢450,000 and ¢600, 000 for a 375 cc container.

2.22.7 *Calabash*

This is made from the dry shell of the gourd plant. The choice of material is limited. It is the cheapest packaging material and shea butter packaging is mainly done traditionally in calabash. The fresh gourd is cut open and seeds and pulp removed, washed and dried. They come in various sizes and are able to withstand very high temperatures**.**

2.22.8 *Availability of Packaging Materials in Rural Areas*

In some rural areas the choice of packaging material may be limited or difficult. Ceramics are available for sale in the entire country, although the quality might vary a little and large-scale manufacture can only be found in the coastal and urban areas, such as Accra, Takoradi and Kumasi. Glass products can also be found in the urban areas but new glass bottles or imported jars will not be for sale in rural areas. Rural markets, however, do often offer recycled glass bottles and jars. Plastic manufacture takes place in Accra, Takoradi and Tema only. However, most of the manufacturers have a regional branch in Kumasi. Many traders in rural areas offer a large variety of plastic containers, but will in most cases not be able to provide information on the characteristics of the plastic products. This leads to many rural small-scale producers using inappropriate plastic containers and films. Calabash is however available all over the country especially in the northern regions**.**

TABLE 10: AVAILABILITY AND CHARACTERISTICS OF THE DIFFERENT PACKAGING MATERIALS

OPTIONS	AVAILABILITY	PRICE	SHELF LIFE	PRESENTATION	OTHER
Glass bottles	**Tropical Glass Factory in Abosu, West Africa**	**About ¢300 for 357cc bottle**	**High when well closed**	**Optimal**	**Cooking requires equipment**
Glass jars	**Not yet locally produced Imported from Ivory Coast or Europe**		**High when well closed**		
Ceramic pots	**Widely spread. Best products From Saltpond Ceramics**	**About ¢150 for 357cc bottle**	**Medium when well closed**	**Not transparent but attractive**	**Screw corks can be made**
Plastic bottles/jars High Density Polyethylene (HDPE)	**Plastic Factories in Accra. Widely used.**	**Between ¢150 and ¢200 for 375cc jar**	**Medium depending on plastic quality**	**Hardly transparent so not attractive**	**Sealing needs attention**
Low Density Polyethylene (LDPE)	**Plastic Factories in Accra.**		**Low since hot filling not possible**		
Polyvinyl Chloride (PVC)	**Widely used and produced in Accra**	**About ¢200 for 375cc jar**	**Low since hot filling not possible**	**Can be almost transparent so attractive**	**Sealing needs attention**
Polypropylene (PP)	**Widely used and produced in Accra**	**About ¢150 for 375cc jar**	**High when well sealed**	**Clearer than HDPE but not attractive**	**Sealing with foil advised**
Plastic films (LDPE)	**Widely used and produced in Accra**	**Between ¢10 and ¢20 for a 3755cc pack**	**Low since films are not airtight**	**Not attractive**	

Source: FIT (1994)

2.22.9 *Appropriateness of the Packaging Options for Shea Butter*

Some characteristics of the various packaging materials need to be studied to find out whether they are appropriate for the type and volume of products to be packed. These include the prices, resistance to contamination and temperature, possibilities for recycling, distribution, transport, and storage life. Skills and equipment, shelf life and state of the packed shea product's attractiveness of the material are also important to know.

i. Price

The price of the different packaging options seems to be the most important variable in the selection process. Price margins for small-scale production at a rural level are extremely small, due to the limited purchasing power of the rural population. For the type of food, pharmaceutical and medicinal product being considered in this study, prices differ only marginally between the various options. Only glass products seem to be a little bit more expensive. It is difficult to determine precise prices, since they vary with the availability and price of the raw material required. The following list attempts to give some indications for prices of simple 375 cc containers:

- Ceramic jar - ¢1500
- Glass bottle - ¢3000
- HDPE jar - between ¢1500 and ¢2000
- PP jar - ¢1500
- PVC jar - ¢2000
- Plastic films - between ¢500 and ¢1000

ii. Resistance to Contamination

Air and moisture tightness depend both on the material and the kind of seal used. Ceramic products only are tight when they are properly glazed. Usually a combination of seals is applied (wax / foil and a bung, insert or cap). Nevertheless, tight sealing remains difficult, when not impossible. Glass bottles and jars provide the best protection against contamination-sealed air and moisture tight and can contain a vacuum without difficulty. Plastics vary in their resistance. LDPE and HDPE have a poor barrier against oxygen and CO_2, which can cause decolourization of the shea butter. PVC and PP provide better protection, although attention should be given to the sealing process. Combination of a cap and a foil or film should be considered to provide optimal air and moisture tightness.

iii. Temperature Resistance

Since we look into packaging options for products that tend to be packaged at high temperatures, the material should be able to resist between 80°C and 90°C. That offers no problem for the glass and pottery products, but only the HDPE and PP plastic varieties stand these temperatures. LDPE (containers and films) and PVC tend to deform at temperatures above 60°C so they seem not to be appropriate for packaging shea butter. When we suppose that packaging material should be sterilized before use (which is not necessarily the case for new material), also the HDPE variety will not be appropriate.

iv. Possibilities for Recycling

The temperature resistance of the packaging material is also important when we look into the possibilities for recycling. For a proper re-use of the material for the same products, the containers need to be sterilized at a temperature above 100°C; it has been seen that LDPE and PVC do not stand these temperatures. Also HDPE tends to deform at temperatures above 90°C and can, therefore, not be sterilized. Plastic films cannot be re-used. Apart from the glass and ceramics products, the only plastic variety that can be properly recycled for the same use is polypropelene.

v. Transport

Transport of the packaging material to the rural areas and transport of the packed product to its consumers faces the following constraints.

i. Ceramic and glass products are heavy and break easily when subject to shocks. They cannot be stacked. When packed carefully during transportation, however, they are strong under compression. Pottery products are difficult to seal so are likely to leak when not transported vertically.

ii. Plastic containers are light and will not break easily. They are easy to transport (empty and filled) especially when they are conically shaped and can be stacked when empty

iii. Plastic films are easily transported when empty, but, once filled they are very vulnerable to shocks and need to be packed in outer cartons or boxes.

vi. Skills and Equipment

For the packaging material that is available in Ghana, little equipment is needed, except for some sealing methods, such as crown corking or heat sealing. Crown corkers are currently not available in Ghana, although their production should not offer difficulties. Heat sealers are available, but foils can also be sealed with a heated plate or a domestic iron. With respect to the skills needed to select the most appropriate packaging material, a lot remains to be improved. Most small-scale food processors do not possess adequate knowledge of packaging material. Many of them do not know that institutes, such as the Food Research Institute, the Department of Nutrition and Food Science, University of Ghana, the Industrial Research Institute and the Ghana Standards Board are able to provide appropriate information on packaging options. Special attention should be given when plastics are used for packaging. The various types of plastic available in Ghana have, as we have seen, very different characteristics and retailers of plastic containers are in most cases not able or willing to provide adequate information on the type of plastic and its properties as well as suitable applications.

vii. Attractiveness

An attractive package increases sales when prices can be kept competitive. Products become more attractive when they are packaged in material which appeals to the customer. This shows attention has been given to every step in the production process, can easily be reused for other or the same purposes or comes with an attractive and informative label. Attractiveness also relates to the transparency of the packaging material, as consumers want to see what they buy, especially when the product is new and/or unknown. However, it should be kept in mind that attractiveness is subjective and related with culture, so it can vary from country to country and even from region to region. This means that the destination market or country is crucial in the choice of attractiveness especially of design and colour of packaging. Glass jars and bottles are considered as very attractive and highly transparent packaging materials. Ceramic pots, although not transparent, can appeal to the potential customer since they can easily be re-used. Plastic containers mostly are only little transparent (PP can be rather clear and PVC almost transparent). Plastic films are not attractive compared with the other options. All products can easily be labelled.

3.0 MATERIALS AND METHODS

The materials and methods used for conducting both the field surveys and the laboratory studies have been outlined. The entire studies were conducted in Ghana between November 2004 and March, 2009.

3.1 Methodology for Jatropha Oil Data Collection and Technology

The methodology used for the data collection involved the following steps:

i. Local level baseline information collection through secondary information and interviews

ii. Problem identification through the use of participatory rural appraisal method to identify and assess development needs, get insights of socio-cultural and institutional settings through the use of secondary data, local knowledge and perception of the rural area.

iii. Demonstration, awareness raising and adaptation.

iv. Dissemination, capacity building and market development for technologies transfer within the locality.

v. Participatory monitoring and evaluation at all levels.

A semi-structured questionnaire was administered to assess the socio-economic profile of the Gbimsi women's group consisting of forty-two women. A sample of the questionnaire can be found as Appendix 1. A pilot Jatropha plantation was established for the Gbimsi women's group. The plantation was intercropped with peanuts and cowpeas. In addition to the plantation, a pilot-processing unit was also established. Some of the equipments installed were a dehuller, disc attrition mill and a solar heater. The women were also taken through how to operate and maintain the equipment. Training on how to extract biofuel from the Jatropha plant, book and records keeping, operation and maintenance of the biofuel extraction plant, utilization of Jatropha oil in diesel engines and lanterns, manufacture of soap using the Jatropha oil and gender sensitization was conducted. The main components of the biofuel processing plant consisted of three bridge presses, a Jatropha seed dehuller, disc attrition mill, solar heater, and 8HP diesel engine.

3.1.1 *Collection of Kernels*

The collection of kernels for the initial trial before the maturity of the plantation was well organized and young men were paid to collect the kernels from the wild in some regions of Ghana. However, when the plantation matured, families comprising mainly women and children usually did the collection of the kernels. Collection begins at early dawn and proceeds until about mid-day, when the heat of the sun compels collectors to retire. Collectors have to move from one line of shrubs to the other gathering matured kernels on the shrubs and underneath and it has been estimated that collectors move throughout the radius of the farm. The limitation is due to problems of transportation of the load since all the transportation is presently done on foot by head loads.

3.1.2 *Production of Biofuel at Gbimsi*

The new method, which was successfully field tested in Gbimsi a village in the Northern Region of Ghana, is still used by the women processors and involves deshelling with a sheller and grinding dry kernels (normally at a moisture content of between 4-6 %) into paste, using a local Disc Attrition Mill (Fig. 7) and a dehuller (Fig. 8).

Figure 7. Seed Milling Using Disc Attrition Mill

Source: From Author's Field Work

Figure 8. A Dehuller Unit

Source: From Author’s Field Work

The paste obtained soon after milling, is usually at a temperature of about 70 °C, and allows for the processing of the paste with further heat treatment in a solar heater (Fig. 9). The paste is prepared for pressing, by raising its moisture content to 12 % through kneading with a predetermined amount of hot water. The moisturized paste, upon attaining a temperature of about 60 °C is put in small bags, and pressed in bridge presses to release the oil (Fig. 10).

Figure 9. Solar Heater.

Source: From Author's Field Work

Figure 10. Women in Northern Ghana Extracting Biofuel from Jatropha Seeds

Source: From Author's Field Work

Advantages of this method which is similar to the method used in shea butter extraction explained at Page 7 include the following:

i. Increase in extraction efficiency by 5% of the normal extraction rate.

ii. Increase in daily production capacity by 200%.

iii. Drastic decrease in firewood consumption: About 8 kg of firewood for this method for every 95 kg of kernels processed.

iv. Drastic decrease in water use. About 8 litres of water for this method for every 95 kg of kernels processed.

v. Reduction in the extraction operations from 7 to 5 by the removal of roasting and cream boiling operations, both of which are time-consuming, wastes a lot of firewood and water, and expose the women to excessive heat and smoke.

vi. Light golden colour oil is extracted and there is direct use of oil in engine of the attrition mill.

vii. The process is environmentally friendly and it saves wood fuel and conserves water. It does not produce any effluent, but rather the cake produced after the oil extraction can be dried and used as fuel for burning and fertiliser on farm lands. The breakthrough in technology development has led to increased volume of oil produced.

3.1.3 *Processing of Biofuel from Jatropha at Gbimsi*

The procedure followed under the study for the processing of biofuel from the Jatropha seeds is described in Figure 11 as follows:

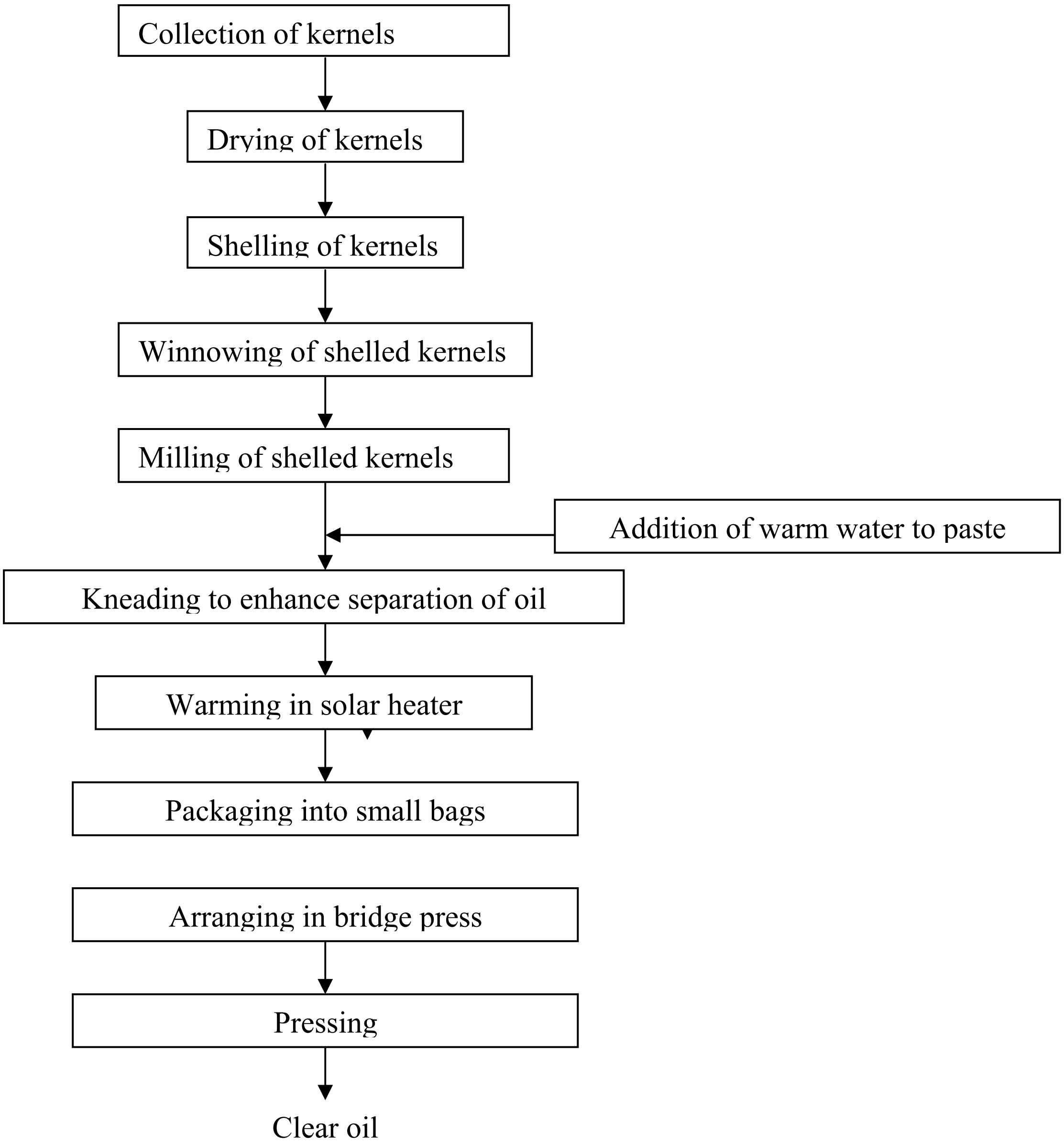

Figure 11. A Scheme for the Processing of the Kernel to Extract Oil

Source: From Author's Field Work

3.1.4 *Physicochemical Analysis of the Biofuel*

Samples of the Jatropha oil produced by the women were taken to the Tema Oil Refinery (TOR) chemical laboratories for physico-chemical analysis. The oil samples were analysed for its density at 15 °C, flash point, colour and sulphur content using the test methods outlined below.

Flash Point – A brass test cup of specified dimension was filled to the inside mark with the Jatropha sample and fitted with a cover, heated and the specimen stirred at specified rates. The ignition source was directed into the test cup at regular intervals with simultaneous interruption of the stirring, until a flash point was detected and then reported.

Density – The Jatropha oil sample was brought to a specified temperature and a test portion was transferred to the hydrometer cylinder that had been brought to the same temperature. The hydrometer at the same temperature was lowered into the test portion and allowed to settle. After an equilibrium temperature was reached the hydrometer scale was read and the temperature of the test portion was read. The observed hydrometer reading was reduced to the reference temperature by means of a table.

Colour – The height of a column of sample was decreased by levels corresponding to colour numbers until the colour of Jatropha sample was unmistakably lighter than that of the standard. The colour number above that level was then reported.

Sulphur – The Jatropha sample was placed in a beam emitted from an X-ray source. The resultant excited characteristic X-radiation was measured and accumulated count was compared with counts from previously prepared calibration samples to obtain the sulphur concentration in mass percentage.

3.1.5 *Use of the Biofuel*

The extracted oil was then used to test run the Lister-type engine of the processing machines. These engines are of Indian origin. Various Jatropha oil: mineral diesel oil ratios were used to test run the engine. The performance of the engine was determined by observing how fast the machine could run and also observing the sound produced by the engine. The various Jatropha oil: mineral diesel fractions used were: 100% Jatropha, 90%, 80%, 70%, 60%, 50% etc of oil with the remaining percent being diesel was used to test run the engine. The Jatropha biofuel was also used in local lanterns as well.

For the study shea butter was processed using the Jatropha biofuel as fuel source for the engine of the machine from the production point in Gbimsi near Tamale in the Northern Region of Ghana. Packaging materials namely, metal can, polyethylene bag and plastic containers were obtained from the Cans and Plastics Limited in Accra, whilst calabash was also obtained from a local producer in Tamale and used for the study.

3.2 Methodology for Shea Butter Data Collection and Analysis

A field survey was conducted and questionnaires administered.

3.2.1 *Field Survey - Sampling and Sample Size*

The multistage sampling method was adopted to ensure representativeness and avoidance or reduction of biases and errors in the sampling. Initially, the purposive sampling method was used to select only people who were either involved in shea butter production or export or both. The quota sampling method was used to select ninety producers and ten exporters.

3.2.2 *Data Collection – Questionnaire Administration*

Ninety (90) shea butter producers and ten (10) exporters were randomly selected from four regions in Ghana namely, Northern , Upper East, Upper West and Greater Accra regions, and questionnaires administered to them. A total of three communities were selected from three districts in each of the four regions for the data collection. Two sets of questionnaires were administered to the respondents; the first set was administered on the ninety (90) producers and / or consumers whilst the second set was administered on the ten (10) exporters. The survey was conducted in the Northern, Upper East and Upper West Regions because of their knowledge on shea butter production and usage. The Greater Accra region was also selected because that is where most of the shea butter marketing and export is done.

Primary data were obtained mainly through interview and administration of questionnaire. Secondary data were collected through the analysis of available information on shea butter production and exportation. The interview schedule was used to gather information from the producers/consumers and the exporters on the Knowledge, Attitudes, Beliefs and Practices (KABP) of shea butter production, consumption and export. The questionnaire used (Appendix 1) were prepared in English but a local person was selected to read out the questions and translated them in the local dialect for the respondents whilst their responses were in turn translated back to English for the completion of the questionnaire during the interview schedule. Deskwork involved discussions with government agencies, NGOs, research institutions and private sector companies engaged in promoting, facilitating or marketing products from the industry.

3.3 Laboratory Studies

The laboratory analysis was done at the Cocoa Processing Company laboratory in Tema, Ghana.

3.3.1 *Sample Collection for Analysis*

Freshly produced shea butter samples processed using Jatropha bio-fuel as engine fuel source were obtained in Tamale in the Northern Region of Ghana and transported immediately to the laboratory (within one day) for analysis. The samples were then put into the already prepared containers (metal can, polyethylene bag, plastic container and calabash) (Fig. 12) to be used for the subsequent analysis. The containers for the shea butter were dried, cleaned and free from foreign odour. They were of such texture and make that metallic contamination of the fat was inhibited. The containers carried labels displaying boldly and conspicuously names of the specific container and the content they are holding.

The samples were kept under open air (28-34 °C), tropical ambient (26-31 °C) and refrigeration (4-7 °C) conditions for a period of three months. Samples were analysed immediately after processing and after 1, 2 and 3 months in storage, for the following chemical indices; Moisture content, free fatty acids (as oleic acid), iodine value, acid value, peroxide value, saponification value and unsaponifiable matter. The physical indices analysed were specific gravity, melting point and slip point.

Figure 12. Sample of Prepared Containers (Metal Can, Polyethylene Bag, Plastic Container and Calabash)

Source: From Author's Laboratory Work

3.3.2 *Experimental Design:*

A 4 x 4 x 3 factorial experimental design was used for the study and the principal factors investigated were;

i. Storage conditions: Open air (28-34 °C), tropical ambient (26-31 °C) and refrigeration (4-7 °C).

ii. Storage time: 0, 1, 2 and 3 months.

iii. Packaging materials: Metal can, polyethylene bag, plastic container and calabash.

The products (sample size of 48) were analysed in the laboratory. There was simulation of the actual Ghanaian market situation conditions where the shea butter was left in the sun for eight hours, cooled over night and repeated several times for a period of time and analysed. The study was both explorative and experimental design. It is explorative because it is a small-scale study of a relatively short duration and very little information is known about shea butter production. It is experimental in that laboratory investigations were made to assess the effects of the different packaging materials on the quality of shea butter.

3.4 Analytical Methods

The laboratory analysis was done at the Cocoa Processing Company laboratory in Tema, Ghana

3.4.1 *Moisture Content Determination*

Moisture content of the shea butter was determined using the AOAC (1990) method 926.12 with slight modification as outlined below;

Procedure:

The sample was softened with care to prevent it from melting, and was thoroughly mixed. About 0.5 g of the sample was weighed into aluminium dishes of 5 cm diameter and 2 cm deep and covered with tight-fitting covers. They were then dried to constant weight in a vacuum at uniform temperature of 10 °Ċ above the boiling point of water at working pressure, which was around 100 mmHg. They were then cooled in a dessicator for 30 minutes and weighed. Constant weight was attained when successive one hour drying periods showed additional loss of 0.05 percent or less. The percentage loss of weight was reported as moisture. Three trials of each sample were taken and the results were taken and recorded.

3.4.2 *Free Fatty Acids*

Free fatty acid (FFA) content of the shea butter was determined using the method described by Egan *et al.* (1985) as outlined below;

Procedure:

Two grams of shea fat was accurately weighed into a 250 mL conical flask with a glass stopper. A mixture of 25 mL, diethylether, 25 mL ethanol and 1mL 1% phenolphthalein, carefully neutralized with 0.1 N NaOH was added and rotated gently to dissolve the oil. The content was titrated with aqueous 0.1 N NaOH, with constant shaking until a pink colour which persisted for at least 15 seconds was obtained. The free fatty acid (FFA) was calculated as follows:

% FFA = (Vol. Of 0.1 N NaOH x 0.028 / Weight of shea butter analysed) x 100

The determination was done three times and the average value recorded.

3.4.3 *Peroxide Value*

The determination of peroxide value of the shea butter was done using the AOAC (1990) Titration Method 965.33.

3.4.4 *Saponification Value Determination*

Saponification value of the shea butter was determined using the method described by Egan *et al.* (1985) with slight modification as outlined below;

Preparation of Reagents

Potassium hydroxide solution: Potassium hydroxide solution of 0.5M, in 95% (v/v ethanol) was prepared. Thirty-five (35) grams of potassium hydroxide pellet was dissolved in 20 ml water, and the solution mixed with 1000 ml of 95% ethanol. The solution was allowed to stand for 12 hours at room temperature and the clear supernatant solution decanted off. The filtered solution was then kept in the dark for storage. Hydrochloric acid of 0.5M and 0.5 mole/L was accurately standardized and a 2% phenolphthalein indicator prepared.

Procedure:

Two (2) grams of the shea butter sample was accurately weighed into a 250 ml conical flask and 25 ml of alcoholic potassium hydroxide solution was measured into the flask. The flask was connected with a condenser and refluxed continuously for 1 hour, swirling intermittently until complete saponification. The flask was removed and the content titrated against the 0.5N HCL, using phenolphthalein as an indicator. The end point was reached when pinkish colouration changed to colourless. Blank determination was conducted along with that of sample, using same reagents minus sample. Saponification value was calculated and expressed as the number of milligram of KOH required to saponify 1 g fat.

3.4.5 *Determination of Unsaponifiable Matter*

The unsaponifiable matter of the shea butter sample was determined using a modified AOAC (1990) method as described below;

Preparation of Reagents:

Alcoholic potassium hydroxide: Alcoholic potassium hydroxide (2N) was prepared by dissolving 80 g of KOH pellets in 20 ml distilled water and the solution mixed with 500 ml 95% v/v ethanol and allowed to stand overnight. The clean supernatant liquid was then filtered off. Petroleum Spirit, ethanol – 50% (v/v), concentrated sodium chloride and acetone were also prepared and kept.

Procedure: About 2.5 g of the butter was weighed into a 250 ml flask and 25ml ethanolic KOH solution added. The flask was attached to a reflux condenser and heated for one hour, swirling the flask intermittently until saponification was complete. Twenty-five (25) ml distilled water was added and the heating stopped. It was allowed to cool to room temperature. A blank was run with all reagents. The solution was transferred to a 250 ml separator. The flask was rinsed five times with 10 ml portions of petroleum spirit and added to separator. It was shaken vigorously for 1 min., periodically releasing pressure by inverting the separator and opening the stop cock. It was allowed to stand until separation was nearly complete. The soap solution was drained as completely as possible into a second 250 ml separator. Upon emulsion formation a few ml of concentrated sodium chloride was added. The extraction was repeated twice with two 25 ml portions petroleum ether and combined petroleum ether extracts which was washed 3 times with 25 ml portions dilute ethanol (50%). The last wash was checked with phenolphthalein and when alkali was present it was rewashed and rechecked. The solution was poured into weighed flask and evaporated to about 5 ml on a steam bath. It was then dried for 1 hour at 100 °C and cooled for 1 hour in dessicator. About 2-3 ml acetone was then added and reheated. The residue was dried for 30 minutes at 100 °C in an oven placing flask horizontally. It was cooled for 1 hour in a dessicator and weighed. Drying, cooling, and weighing were repeated after each drying period, until change of weight was less than 1.5 mg. The sample was discarded after third weighing. The unsaponifiable matter was then calculated and expressed as a percentage.

3.4.6 *Iodine Value Determination*

Iodine value of the sample was determined using the method described by Egan *et al.* (1985) with slight modification as outlined below;

Preparation of reagents:

Carbon tetrach1oride, inert to Wijs' solution and Potassium iodide, free from iodate, 10 % solution were prepared. Starch indicator, 1 % solution, was prepared by adding 1 g of soluble starch and thoroughly mixed with a small quantity of water, and the mixture diluted to l00 ml, brought to the boil and cooled to room temperature before use. Sodium thiosulphate, 0.IN solution was accurately standardized.

Procedure:

Wijs' solution 8 g of iodine trichloride was dissolved in 200 ml glacial acetic acid. About 9 g of iodine was dissolved in 300 ml carbon tetrachloride. The two solutions were mixed and diluted to 1000 ml with glacial acetic acid. The melted fat was poured into a small beaker, a small rod added and a suitable quantity of the sample was weighed by difference into a dry glass-stoppered bottle of 250 ml capacity. Ten (10) millilitres of carbon tetrachloride was added to the melted fat and dissolved. 20 ml of Wijs' solution was added; the stopper inserted and allowed to stand in the dark for 30 minutes. Fifteen (15) millilitres of potassium iodide solution and 100 ml of water were added, mixed and titrated with 0.1M thiosulphate solution using starch as indicator just before the end-point. A blank was carried out at the same time commencing with 10 ml of carbon tetrachloride. The trial was repeated three times for each sample and the average recorded.

3.4.7 *Acid Value Determination*

Acid value of the sample was determined using the method described by IUPAC (1979) and modified by Egan *et al.* (1985) as outlined below;

Procedure:

Twenty-five (25) millilitres of diethyl ether was mixed with 25 ml hot neutral alcohol and 1ml of phenolphthalein solution (1 per cent) and carefully neutralized with 0.1M sodium hydroxide. About 5g of the melted fat was dissolved in the mixed neutral solvent and titrated with aqueous 0.1M sodium hydroxide shaking constantly until a pink colour which persisted for 15 seconds was obtained. The acid value of the fat was then calculated using the free fatty acid equation which expresses the FFA as oleic acid (1 ml 0.1 M sodium hydroxide) and the acid value obtained as 2 x FFA.

3.4.8 *Specific Gravity Determination*

The determination of specific gravity of the shea butter was done using the AOAC (1990) Pycnometer Method 920.212.

3.4.9 *Melting Point Determination*

Melting point of the sample was determined using a modified Capillary Tube Method described by AOAC (1990) Method 920.156 as outlined below;

Procedure: A thoroughly clean glass tube was inserted into solid shea butter for the fat to rise to 1± 0.2 cm long in the column. The tube was then fixed to a thermometer with the aid of a rubber band. The thermometer was immersed into a beaker containing 100 ml of water at 20 °C so that the lower end of the fat column was 3 cm below the surface of the water. The beaker containing the thermometer was then immersed into a water bath between 30 to 40 °C. The temperature at which the column of fat in the tube rose under the hydrostatic pressure of water was noted. The procedure was repeated 3 times and the average temperature was determined and calculated to obtain the melting point.

3.4.10 *Slip Point Determination*

The determination of slip point of the shea butter was done using the method described by Minifie (1989) as outlined below:

Procedure: About 30-50 g of the shea butter was transferred to a small, clean and dry beaker, melted by warming in an oven until the temperature was 55-60°C, cooled with occasional stirring until the temperature was 32-34°C and stirred continuously until the first sign of cloudiness appear. When a pasty consistency was achieved, the fat was transferred quickly to a mould that has previously been stored at 15-22°C. The fat was then stored at 15-22°C for 24 hours until use for the testing.

Determination : A wisp of cotton wool was rolled between the thumb and forefinger and introduced into a capillary tube (5-6 cm long, 1.1-1.3 mm internal diameter, 1.4-1.7 mm outside diameter), then pushed along with a piece of wire until it was 2 cm from the end. The capillary tube was pressed into the fat to obtain a plug of fat 1 cm long in the tube and the tube attached to a thermometer with a small rubber band so that the plug of fat is coincident with the bulb of the thermometer. Previously boiled and cooled distilled water was poured into the beaker to a depth of not less than 6 cm and the thermometer clamped centrally in the beaker so that the lower end of the capillary tube was 4 cm below the surface of the water. A mechanical stirrer was fitted and the water was heated to obtain a heating rate of 0.5°C per minute as the slip point was approached. The point at which the fat starts to rise in the tube was recorded as the slip point of the fat. This determination was done five times and the mean value noted as the mean slip point of the fat.

3.5 Data Processing and Analysis

The Statistical Package for the Social Sciences (SPSS) was used for the analyses of the field survey questionnaires and Microsoft Excel was used to plot all the graphs within the study. Statgraphics Plus 4.1 (Graphics Software System, STCC, Inc, Rockville, USA) examined the chemical properties (moisture content, free fatty acids (as oleic acid), iodine value, acid value, peroxide value, saponification value and unsaponifiable matter) and physical properties (specific gravity, melting point and slip point) using two-way analysis of variance (ANOVA) and multiple range tests to determine effects of storage condition, storage time and packaging material and their interactions. Tukey multiple comparisons at 95% significance determined differences between factor levels.

4.0 RESULTS AND DISCUSSIONS

The results of the study are discussed below.

4.1 Technology Development for Jatropha Biofuel Production for Shea Butter Processing.

4.1.1 *Socio-Economic Characteristics of Women Shea Butter Producers*

The mean age of the women is about 44 years. The age of the group ranged from 25 years to 65 years. Ninety three percent of the women were muslims. A still photograph of a section of the women busily extracting the Jatropha oil was shown in Figure 10 (p. 73). All the women were married with an average of 6 children. Seventy-nine percent of the women were in the extraction of shea butter as the only source of income (Figure 13).

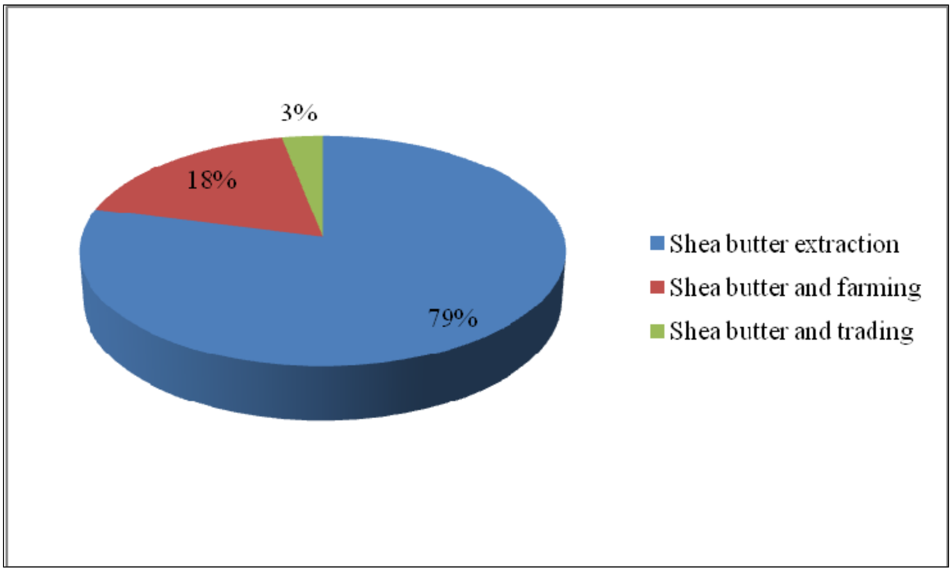

Figure 13. Source of Income for Women

Source: From Author's Field Work

The husbands of all the women were also involved in farming. The food crops produced by the husbands are peanuts, millet, maize, cotton and rice. Almost all the women did not have any formal education (Figure 14) and could not read and write. Mampruli was the language spoken by most of the women. About 13% could speak both 'mampuruli' and 'twi' languages.

Only about 23% of the women were members of other women's groups and associations. Some of these associations were Muslim Mothers' Association, Let's help each other group and Christian women's fellowship.

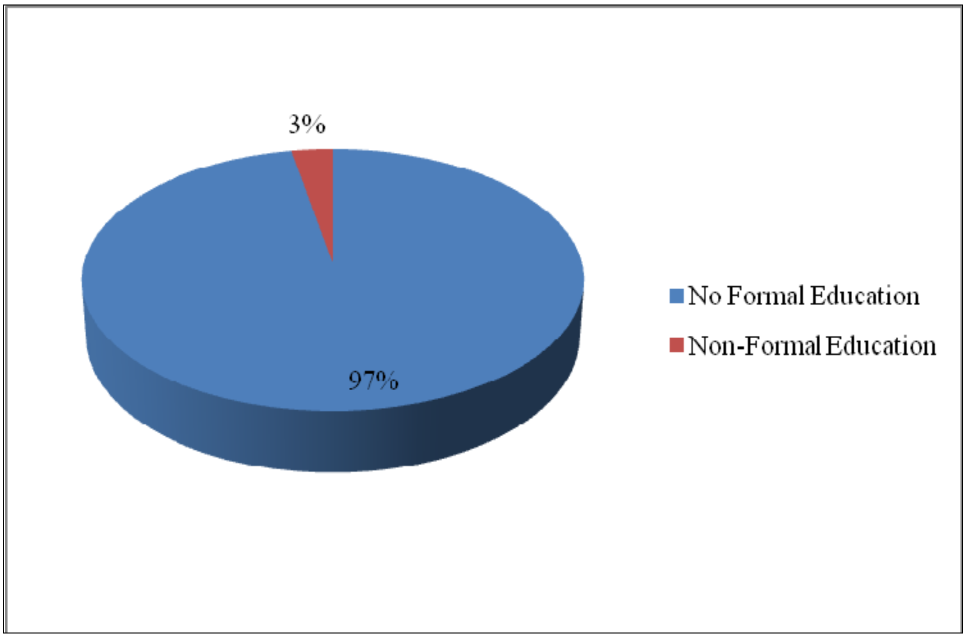

Figure 14. Educational Level of Women

Source: From Author's Field Work

4.1.2 *Promotion of Women's Sustainable Livelihood*

The Jatropha plantation was successfully done using cutting and seed grown directly in the fields. The production of seed was about 1.5 kg per meter of hedge per yard and around 2 kg per plant. The collection of kernels for the initial trial before the maturity of the plantation was well organized and young men were paid to collect the kernels from the wild in some regions of Ghana. However, when the plantation matured, families, comprising mainly women and children, did the collection of kernels. Collection began at early dawn and proceeded until about mid-day, when the heat of the sun compelled collectors to retire. Collectors had to move from one line of shrubs to the other gathering matured kernels on the shrubs and underneath and it has been estimated that collectors move throughout the radius of the farm. The limitation is due to problems of transportation of the load since all the transportation is presently done on foot by head loads.

With respect to intercropping peanuts with the Jatropha plants, it came to light that, a yield of 54 bags of peanuts was realized after the intercropping. The cultivation and use of Jatropha oil provided an alternative source of income for the women. The women sold the oil to other women's groups for use in local lanterns. The cowpeas and peanuts intercropped in the Jatropha plantations were also sold.

A report in the Sustainable energy and development Forum, 2004, showed that the number of women's group involved in the Jatropha activities in Monduli in Tanzania, increased from three in 2000 to seventeen in 2003. These women's groups engaged themselves in the supply of planting materials, collection and pressing seeds and also processing of oil into soap for sale.

4.1.3 *Physicochemical Analysis of the Biofuel*

A sample of the Jatropha oil extracted is as shown in Figure 15. The biofuel was analysed for density at 15°C, flash point, colour ASTM/SAYBOLT and the percentage of sulphur and the results are shown in Table 11.

Figure 15. Sample of Jatropha Oil Extracted by Women at Gbimsi, Ghana

Source: From Author's Field Work

Table 11. Physico-chemical Characteristics of the Jatropha Oil

Index	Jatropha Bio-diesel			
	Top layer	Middle layer	Bottom layer	Mean
Density at 15 °C (Kg/m^3)	859.8	859.8	862.8	860.8
Flash point CC/PM °C	81	83	84	82.7
Colour ASTM/SAYBOLT	3.0	3.0	3.0	3.0
Sulphur (%wt)	0.47	0.47	0.28	0.41

Source: From Author's Analysis of Jatropha Oil at the Tema Oil Refinery Laboratory

The density of the Jatropha oil obtained was higher than that of mineral diesel oil reported by Argarwal and Agarwal (2007). In their study to compare the performance and emissions characteristics of Jatropha oil (preheated and blends) in a direct injection compression ignition engine, a density of 840 Kg/m^3 was reported. They reported a density of 917Kg/m^3 for the Jatropha bio-fuel they prepared. This value is higher than that observed in the Jatropha prepared in this study.

The flash point of the Jatropha oil was 82.7 CC/PM °C. This value is higher than that of mineral diesel (71 CC/PM °C) as observed by Argarwal and Agarwal, 2007. The higher flash point of the Jatropha oil means that Jatropha is safe to handle when in storage and during transportation, however, a high flash point may result in initial starting problems in engines. The sulphur content of the Jatropha oil was higher than 0.25% of mineral diesel oil reported by Argarwal and Agarwal (2007) although it was within the acceptable range of 1.0%. Higher sulphur contents of the Jatropha oil means higher emission of $S0_2$.

4.1.4 *Use of the Jatropha Oil*

The use of vegetable oils as fuel for diesel engine has long history. The use of Jatropha oil as fuel in internal combustion engines is becoming frequent in the areas where this oil is available as total oil or oil blended with diesel. Although the use of direct oil still requires debate.

The Jatropha oil was combined with various fractions of mineral diesel oil and tried in Lister-type internal combustion engines. The trial indicated that, a combination of 30% mineral diesel oil to 70% Jatropha (BD70) bio-fuel was the best and was successfully used to power the engine that powers the attrition mill used by the women for shea butter processing. Some studies have been done on fuel properties of Jatropha oil-diesel blends and engine performance by Bhattacharya (2005) and it was found that blending of Jatropha oil with diesel was feasible up to 30:70 oil-diesel blend. The performance of the engine in respect of brake power, hourly fuel consumption; emission of CO, UBHC and NOx under the rating test was found to be satisfactory.

In an earlier study by Forson et al. (2004), the performance of diesel/Jatropha fuel blends in a diesel engine was tested in Ghana. Three blends were obtained by mixing diesel and Jatropha oil in the following proportions by volume: 50% diesel/50%

Jatropha oil; 80% diesel/20% Jatropha oil and 97.4% diesel/2.6% Jatropha oil. The study concluded that 97.4% diesel/2.6% Jatropha oil fuel blend competed favourably with diesel fuel and offered a reasonable, if not even a better, substitute for pure diesel fuel. The use of 100% Jatropha bio-fuel (BD100) was found to slow down the operation of the engine. It has been reported that, these inexpensive lister-type diesel engines can run on pure Jatropha oil when a fuel filter is installed on them. Due to the high oxygen content of the Jatropha oil, these internal combustion engines give better results when at maximum loads.

The 100% Jatropha oil was used in local lanterns and was observed that, the lanterns gave smokeless light compared to those that used kerosene. This observation will go a long way to help reduce air pollution in our rural areas where there is a great reliance on lanterns. The lanterns that burned on the Jatropha oils were found to last four times longer than those that burned on kerosene. This means that the Jatropha oil will provide a cheaper source of fuel to be used in the lanterns in the rural communities.

4.2 Field Survey on Shea Butter Producers and Exporters

The various responses provided by the shea butter producers and exporters selected at random from the Northern, Upper East, Upper West and and Greater Accra regions of Ghana after the administration of the questionnaires are elaborated below. The survey sought to gather information from the producers and exporters knowledge, attitude, beliefs and practices of shea butter production, consumption, storage, marketing and export in Ghana.

4.2.1 *Profile of the Shea Butter Producers and Exporters*

A total of ninety (90) shea butter producers in the Northern, Upper East and Upper-West Regions of Ghana were involved in the study. Likewise, ten (10) exporters from the Northern and Greater Accra regions were also involved. Majority (84) of the producers were from the Northern Region whilst four (4.4 %) and two (2.2 %) were from the Upper-West and Upper-East Regions respectively. All the producers interviewed were females with 58 (64.4 %) of them married, 16 (17.8 %) widowed and 10 (11.1 %) being single. Table 12 shows the age distribution of the respondents depicting a high proportion of shea butter producers between the ages of 40 and 60. The age distribution suggests that 93.3% the shea butter producers and users in the studied communities were female adults aged between 40-70 years (Table 12). This shows that majority of shea butter producers in Ghana are very old and this is likely to negatively affect shea butter production in Ghana within the next decade. It is therefore necessary that step are taken to encourage the younger ones to go into shea butter processing if the market is to be sustained after the next decade. This observation of very high numbers of old women shea butter processors agrees with FAO (1997) that in rural communities of sub-Saharan Africa, women are often producers and processors of food and their activities are geared towards the generation of income for the maintenance of their families.

Table 12. Age Distribution of Shea Butter Producers and Exporters

Age Group	Percent Respondents	
	Producers	Exporters
40 – 49	11.1	10
50 – 59	64.4	60
60 – 69	17.8	20
> 70	6.7	10
TOTAL	100	100

Source: From Author's Field Investigation

Unlike the producers, the shea butter exporters were all married males between the ages of 40 and 74, with a mean age of 54 years. Majority (60 %) of the exporters were aged between 50 and 60 years which suggests that the shea butter export business is mainly undertaken by males who have enough capital for business.

A high level of illiteracy (91.1%) was evident among the shea butter producers in the communities studied. Majority 70 (77.8%) of them were Moslems who have had no formal education in their lifetime. Low illiteracy level is a common feature in rural communities in Ghana (Nabilla, 1989). The implication of low illiteracy levels are that of ignorance, a slow cultural, agricultural and nutritional transformation, poorly developed human resource and increased unemployment. As acknowledged by FAO (1997), improved education and literacy can influence the skills and knowledge needed for successful improved agricultural productivity as well as decisions regarding the expenditure of time and resources. Furthermore, education and literacy are fundamental to achieving benefits from policies and can enhance agricultural productivity (FAO, 1996). It is imperative to educate the young shea butter producers and users and as well encourage the educated ones into the shea butter production if the sector seeks to realize its dream of expansion and exploitation of the foreign markets. However, all the exporters had had some form of education in their lifetime. Majority (60 %) had had tertiary education whilst 40 % had studied up to secondary education, suggesting that shea butter exporters are mainly literates who exports shea butter as their business venture.

4.2.2 *Packaging of Shea Butter by Producers*

Packaging of shea butter after production is very important and it is one of the critical factors the producers consider in their effort to make their product available to the market. Traditionally, shea butter producers use calabash for packaging their shea butter with occasional use of leaves or straw basket as temporal packages. Currently, with the onset of modern technologies, new methods of packages have been introduced for the package of shea butter, which includes the plastic and enamel bowls. However, different types of packaging materials are used by different producers due to various reasons. In this study, majority (82.2%) of the respondents used calabash for the packaging of their products for the reasons as listed in Table 13.

The major reason presented by majority (44) of the producers for packaging their shea butter in calabash was that it prevents melting of the product. As well, 28 respondents explained that the calabash is always available, cheap and easily transportable, whereas another 28 respondents said it increases the weight of the product. However, 16 respondents said the use of calabash in packaging shea butter is the traditional way of packaging and therefore cannot give any reason for its use.

Table 13. Reasons for Packaging Shea Butter in Calabash

Reasons	No. of Respondents
Prevents melting of product	44
Available, cheap and easily transportable	28
Increases weight of product	28
Traditional way of packaging	16
Prevents contamination and ensures long storage	14

Source: From Author's Field Work

In spite of the reasons outlined by the producers in using calabash as the appropriate packaging material for the packaging of shea butter, some constraints were as well elaborated as encountered during the use of calabash, stating that;

i. they are expensive

ii. they break easily

iii. they make the butter dirty

iv. they are readily available

v. requires further covering to prevent contamination of the butter

vi. buyers do not return them and therefore one needs to buy new ones after every production.

4.2.3 *Storage of Shea Butter by Producers*

Storage of agricultural products is seen as part of the post-harvest process, a link in the production, storage, marketing and consumption chain. Proper storage is therefore a crucial operation in the production system of shea butter to ensuring premium prices and availability of good quality product at all times. Asked whether the butter gets contaminated / spoiled or not, majority (51.1%) answered in the affirmative.

4.2.4 *Spoilage and Contamination of Shea Butter*

According to those respondents, contamination of shea butter occur through foreign particles or materials prepared with bad nuts or when oil is not cooked well. They however explained that when the processing is done well and the product is well packaged, the shea butter can stay for many months without change in quality. Furthermore, they explained that in order to avoid contamination and spoilage of the product clean materials should be used in the production process, avoiding bad or contaminated nuts and boiling of the oil should be very well done to get any water out of it.

4.2.5 *Reasons for the Storage of Shea Butter*

Shea butter is stored by producers for many reasons and the various reasons given by the producers are presented in Table 14.

Table 14. Reasons for Storing Shea Butter

Reasons	No. of Respondents
To get a good price for the product or to look for market	40
For the butter to solidify and get hardened	16
Depends on the market day	14
To sell in times when one needs money	10

Source: From Author's Field Work

The reason given by majority (44.4%) of the producers was to get a good price for the product or to look for market whereas (20.0%) said they stored their shea butter for the butter to solidify and get hardened before selling. However, 14 (15.6%) respondents said they store to wait for the market day and 10 respondents explained that it enables them to sell in times when they are in need of money. Twenty (22.2%) of the respondents do not store their products at all with the reason that they produce in small quantities and therefore market the butter immediately after production.

Storage quality characteristics are critical in the ensurance of overall quality of products. With the storage of shea butter after processing, majority 62 (68.9%) of the respondents explained that shea butter does not undergo any observable quality changes during storage. They maintained that the product can stay for longer periods of time without any changes in quality. However, a few 28 (31.1%) of the respondents said the butter changes quality slightly during storage. The major explanation given by them is that it loses its scent and undergoes slight changes in colour, appearing pale white instead of its yellowish colour.

4.2.6 *Uses of Shea Butter*

The uses of shea butter are diverse and they can be used in the food, cosmetic and pharmaceutical industries for many different types of products. When asked about the uses of shea butter, all (100%) of the respondents explained that shea butter can be used as cooking oil for frying purposes, skin cream or pomade, soap manufacture, as medicine in the treatment of sores, wounds, boils, skin rashes, treat umbilical cord, reduces temperature of babies and can be put in warm water as laxative for children.

They also explained that the butter can be used as fuel for lighting fire, lubricant for corn mill machines; polish for clay pots and also for smearing trays for baking. All these numerous uses as outlined indicate that shea butter is good and ideal for various purposes.

4.2.7 *Temperature and Quality of Shea Butter*

Temperature changes affect the quality of shea butter during processing and storage of the finished product. This is because when the product is exposed to high temperature it melts and changes quality. When asked about the effect of temperature on the quality of the product, most of the respondents (75.6%) answered in the affirmative that changes in temperature affects the quality of shea butter in that when it is exposed to high temperatures, it melts. Occasionally, the colour changes from yellow to white due to the loss of quality.

In most cases the finished shea butter products are kept in very cold areas within the confines of the house where they are processed to prevent exposure of the butter to the sun. This also aids the solidification of the shea butter and enhances the product quality.

4.2.8 *Considerations in Selecting the Best Packaging Material for Shea Butter*

The factors that are considered in the selection of the appropriate packaging material for shea butter are presented in Table 15.

Table 15. Factors Considered in the Selection of a Good Packaging Material for Shea Butter

Factors	No. of respondents
Resistance to oil and fat	80 (88.9%)
Permeability to gases	16 (17.8%)
Maximum filling temperature	78 (86.7%)
Colour, clarity and surface finish	80 (88.9%)
Need for hand or special closing	78 (86.7%)
Need for bulk packaging	72 (80.0%)
Suitability for contact with food	78 (86.7%)

Source: From Author's Field Work

The major factors considered in the selection of good packaging material for shea butter as explained by the producers were the resistance of the material to oil and fat as well as the colour, clarity and surface finish as responded by 88.9% of the producers. Also, 86.7% reported that the maximum filling temperature, the need for hand or special closing and the suitability for contact with food are other factors they consider in the selection of good packaging material for shea butter.

4.3 Shea Butter Exportation in Ghana

The exportation of shea butter in Ghana is mainly done by only a few individuals whose main source of employment is the shea butter business and exports the shea butter to various parts of the world. The survey collected information on the existing and potential markets, packaging regulations and quality requirements, shea butter packaging and export quality characteristics of shea butter.

4.3.1 *Existing and Potential Importing Countries*

According to the respondents in this study, the countries that import shea butter from Ghana are the United Kingdom, America, Netherlands and Japan. The butter is sent to these countries for the simple reason that, they order for or demand it. Specifically, international or foreign companies such as Aarhus/Loaders, Lever Brothers (Netherlands), Stiabel, some Japanese companies and small-scale producers import the shea butter.

4.3.2 *Packaging Regulations, Quality and Quantity Requirements*

The exporters had no idea of any packaging regulations governing the export of shea butter. The packaging materials that are being used are card box, plastic containers, metal drums and clipped modern boxes. Card boxes and metal drums were adjudged the best for packaging shea butter in that they protect the butter from melting. They are strongly built, thick in dimension and the polyethylene lining ensures preservation toward inflow of moisture and outflow of free fatty acid. They are also good for bulk storage. These packaging materials are preferred since the importers require them, ensure required quality and prevent melting and eventual leakage.

They maintain that they package their product because it allows for easy transportation, ensures safety, prevents contamination, make the product presentable and attractive to customers. Even though they had not experienced any contamination (the butter looking black), in case it happens, the butter is heated or split open to remove the impurities (black spots).

4.3.3 *Weight and Volume of Product*

The mean unit weight of packaged product is 402.33 kg, with the minimum weight being 25 kg and the maximum 1000 kg. The shipment volume is from 10 tons to 500 tons. Specifically, the respondents who export their product to Denmark and America export about 500 tons in two months. Those who export to Japan and Netherlands export about 101.92 tons and the exporter to the United Kingdom also exports about 10 tons.

4.3.4 *Length of Stay at Port of Destination and Transition Period*

With the exception of Denmark, America and Netherlands where the butter stays at the port of destination for five weeks before clearing, that of the other countries are not known to their exporters. The transition period for the export of shea butter to Japan and Netherlands is 3-16 weeks and that of the United Kingdom is about eight weeks. The rest are not known to their exporters.

4.3.5 *Conditions for Export of Shea Butter*

Some conditions in the quality characteristics of shea butter are required to be satisfied before the product can be exported to the importing countries. These include the need to meet the minimum quality requirements stipulated by the importing countries. All these countries have their specific requirements and it is important that all these specifications are met before the products are exported. The minimum quality requirements of shea butter for Japan and Netherlands are that the product should have free fatty acid content between 3.5 - 4, moisture content of less than 1%, acid content between 1.0 - 10.0, and the butter should be creamy yellow in colour. For the United Kingdom, all the above specification must be met and in addition the butter should not be black and must be free from stones (pebbles). For Denmark and United States of America, the free fatty acid should be between 2.0 and 7.0, and if refined, 0.02 - 0.5 and in addition it must be boiled and free from contamination. There are no special specifications for the packaging material that should be used for the export of the shea butter, but all the countries require that the packages used are neat and presentable.

4.3.6 *Requirement of Special Materials*

All the respondents held the view that special materials are required for their product. For Japan and Netherlands, the empty petrol tanker container is preferred as well as insulated aluminum lined metal can of 22 metric tons (22000 kg). For the United Kingdom card boxes are used while for Denmark and America steam jacketed metal tanks are required.

4.3.7 *Traditional and Current/Modern Packaging Materials*

The traditional material used for packaging shea butter is the calabash whereas plastic or metal drums are the modern materials used. The modern materials are obtained from some organisations in Ghana such as Tema Lube Oil. On the aspects of packaging which help in the marketing of the product, majority (75%) of the exporters answered in the affirmative that they consider these factors:

i. resistance to oil and fat
ii. permeability to gases
iii. maximum filling temperature

iv. colour, clarity, surface finish

v. hand or special sealing and

vi. bulk packaging

The length of time for keeping the butter before exporting, according to 50% of the respondents is between 5-21 days. It also takes 7-28 days at the port before shipment depending on availability of ship and the readiness of the ship to depart. The rest had no idea of the length of time.

4.3.8 *Storage and Quality*

All the respondents had never experienced any quality changes during storage of the shea butter. Materials such as aflatoxin in groundnut oils and isothiocynates in rapeseed and mustard seed oil, gossypol in cotton seed oil, naturally occurring may cause concern when these oils are consumed in the unrefined form. The manner in which oil is extracted is believed to have no effect on the glyceride composition, but it does affect the amount and nature of some oils.

4.3.9 *Constraints in Selecting Packaging Material*

Only one respondent admitted that the cost of one drum from Tema Lube Oil Company was ¢120, 000.00 which is quite expensive taking into consideration the quantity of butter exported at any particular time, and this is a major constraint in the shea butter industry. The rest did not express any constraint in selecting appropriate packaging materials for their products.

4.4 Changes in Chemical Properties During Storage

Changes in the chemical properties of fats/oils have been reported to adversely affect their quality during storage and use (Fennema, 1976). These changes are mainly those related to the fat moiety, the nature and degree of stress on the fat/oil and the effectiveness of packaging. In an attempt to investigate the quality characteristics of shea butter during storage, the chemical properties of shea butter were studied to ascertain their quality status during storage under different storage conditions and packaging materials.

4.4.1 *Moisture Content*

Moisture is an undesirable quality in oil since it increases the rate of hydrolysis, which may be explained by the fact that moisture together with impurities contain or provide nutrients for the growth of microorganisms. When sterile conditions are not obtained during handling of the oil, the rate of free fatty acids formation will become dependent on dirt and water present in the oil.

The moisture content of the shea butter studied showed only slight increases during the storage period (Fig. 16). The samples kept under room temperature conditions (26-31 °C) showed consistent increases in moisture content from 0.01 – 0.07 % during the three month of storage with all the four different packaging materials used. Similarly, storage caused moisture increases in the butter kept under open air and refrigerator conditions from 0.01–0.06 % and 0.01–0.05 % respectively. However, the increases observed are acceptable since they are below the maximum moisture limit of 0.51% set by the Ghana Standards Board (1970) for the export quality specification of shea butter.

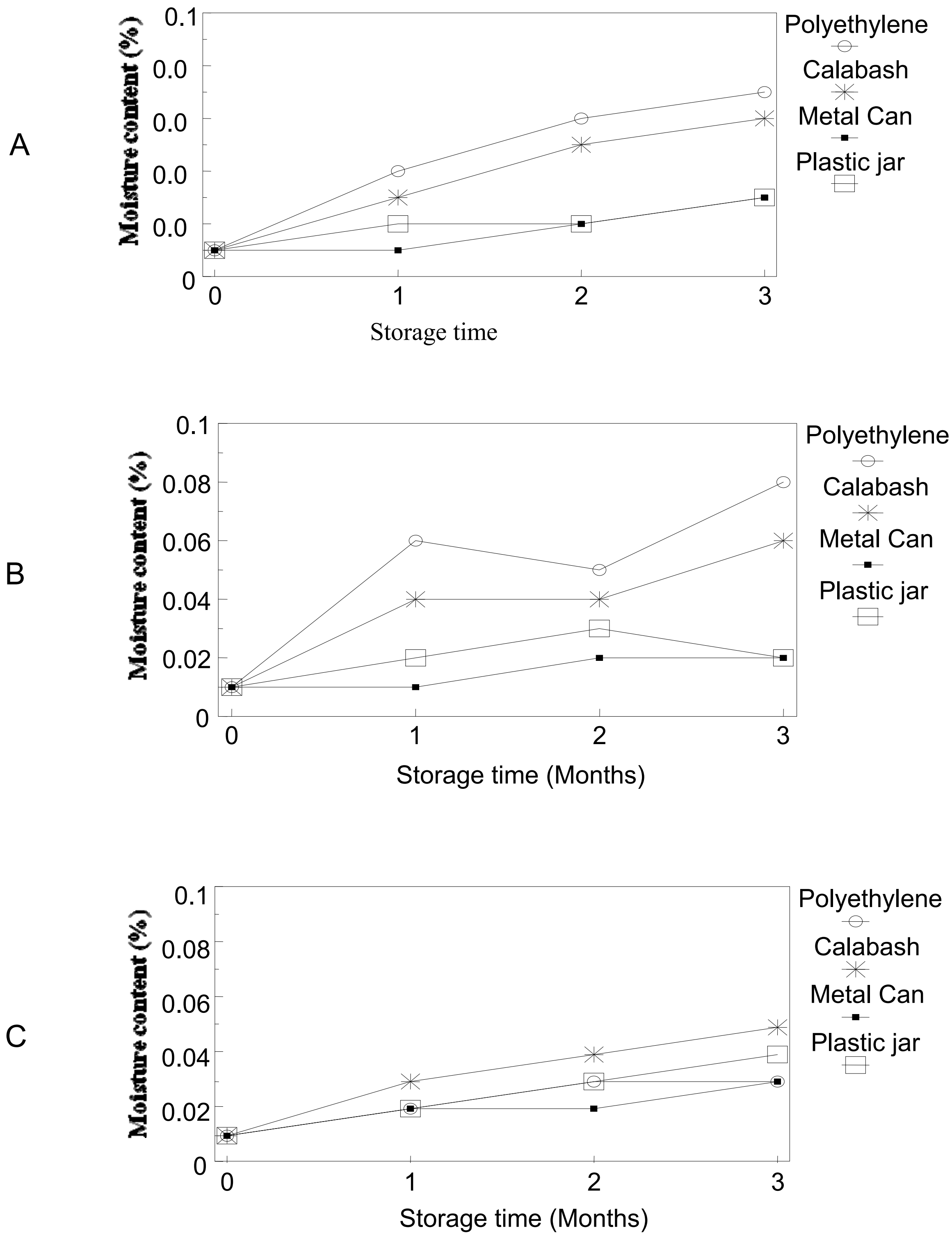

Figure 16. Effect of Storage Condition, Storage Time and Packaging Material on the Moisture Content of Shea Butter (A: Room Temperature (26-31°C), B: Open Air (28-34°C), C: Refrigerator (4-7 °C) Conditions).

Source: From Author's Laboratory Work

This means that within the three months storage period, moisture changes in the shea butter samples were less, indicating no major variations in moisture of the products with storage. The trends of the moisture content of the shea butter during storage under the three different conditions with the four packaging materials are as presented in Figure 16. These trends suggest that the studied shea butter samples did not undergo major moisture changes during storage and therefore shea butter can be stored under ambient and cold conditions without major changes in moisture. Similarly, the type of packaging material used during storage did not influence any moisture changes during storage of the shea butter.

Statistical analysis conducted on the data indicated that the storage condition, packaging material and the storage time did not have any significant effect ($p \leq 0.05$) on the moisture content of the products (Table 16). This suggests that all the packaging materials used could be used to effectively store shea butter for long periods of time without significant changes in moisture.

4.4.2 *Free Fatty Acids (FFA)*

Free fatty acids occur as a result of fat splitting reactions in which the glyceride molecules combine with water to yield free fatty acids, in succession, diglycerides, monoglycerides and free glycerols (Loncin, 1952). This reaction is aided by microbial lipase and its progression leads to the decrease of triglycerols which are the most important constituents of fats and oils, and a corresponding increase in diglycerides and monoglycerides.

The results obtained from the storage studies indicate that the free fatty acid levels were generally affected by storage time and storage condition. Storage caused relatively higher increases in free fatty acid levels of the shea butter kept under room temperature and open air conditions as compared to those of the samples kept under refrigerated conditions (Fig. 17). The FFA levels of the samples increased from 3.29 to 4.86 % and 3.29 to 3.87 % respectively for samples kept under room temperature and open air conditions during the storage period. Similar increasing trends in FFA were noted for the samples kept under refrigeration conditions from 3.29 to 3.44 % within the three months of storage. These increases observed in the FFA levels of the shea butter during storage suggest that the butter undergo different levels of oxidation reactions in the butter leading to the formation of FFA in the butter during storage. The relatively higher increases recorded for the samples kept under room temperature and open air suggest that the exposure of butter to air allows for the rapid oxidation of the fat during storage as compared to samples kept under refrigeration conditions. Egan *et al.* (1985) explained that the decomposition of fat to FFA is accelerated by heat or light and the level of rancidity accompanied by the formation of FFA gives a general indication of the condition and edibility of the oil.

The packaging material used also influenced the FFA level during storage. It was observed that sample packaged in polyethylene bags showed comparatively higher increases in FFA as compared to those of the calabash, metal cans and plastic jars. The higher increases in FFA observed in the samples packaged in the polyethylene bags and stored under open air conditions affected the quality of the stored product, and hence should be discouraged. This indicates that the polyethylene packages enhance the formation of FFA in shea butter as samples are exposed light.

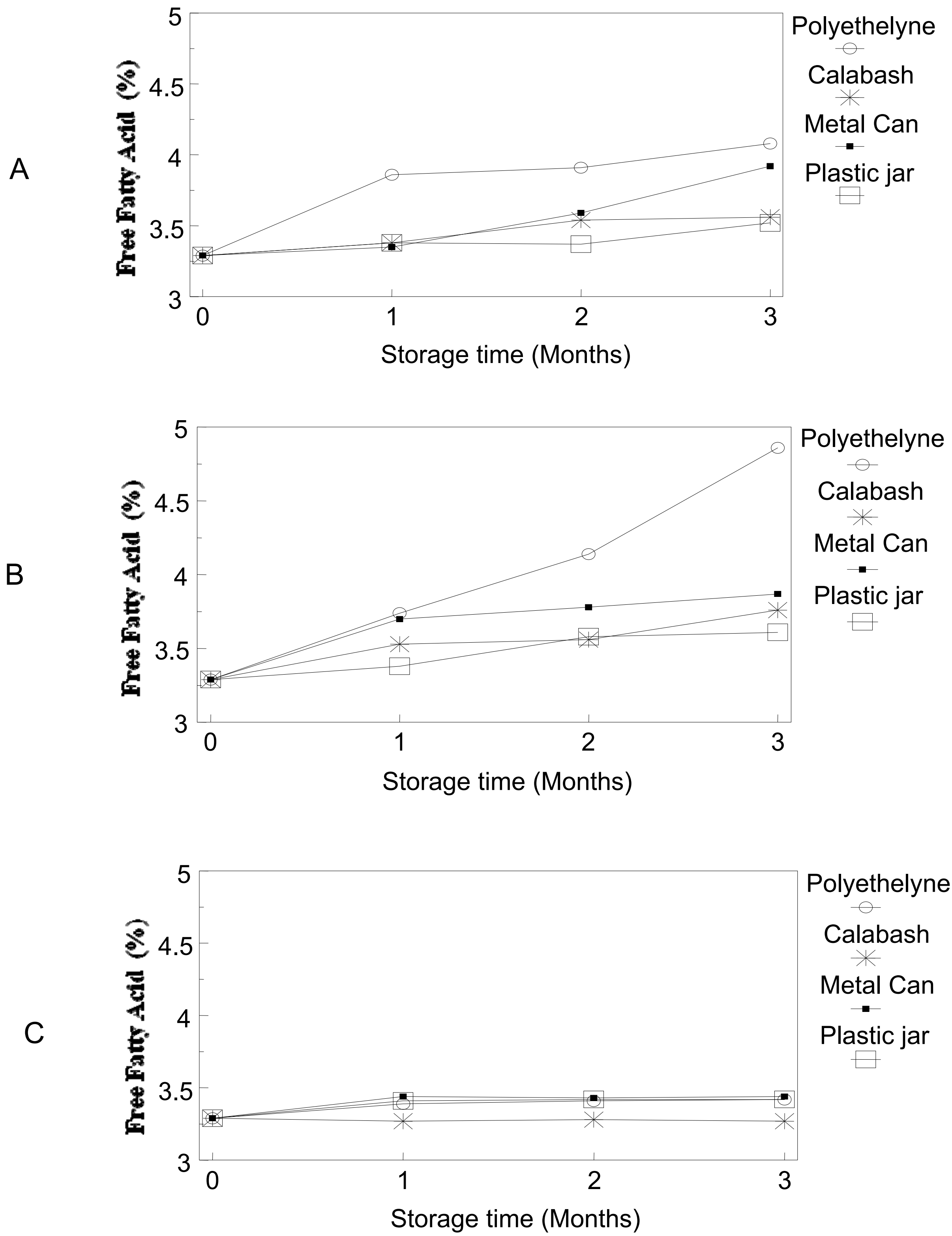

Figure 17. Effect of Storage Condition, Storage Time and Packaging Material on the Free Fatty Acid Level of Shea Butter (A: Room Temperature (26-31°C), B: Open Air (28-34°C), C: Refrigerator (4-7 °C) Conditions).

Source: From Author's Laboratory Work

Analysis of variance conducted on the data indicated that storage time, storage condition and packaging material significantly affected ($p<0.05$) the FFA levels of the butter (Table 16). This explains that all the three factors studied affect the FFA level of shea butter during storage. A two-factor interaction conducted however showed no significant effect between packaging material and storage time, implying that even though the different packages used influenced the FFA levels, the effects of the packages were not significant during storage (Table 16). However, the increases in FFA observed in the butter during storage were not high enough to affect the exportable quality of the butter with the exception of the butter packaged in polyethylene bags and stored under open air conditions.

4.4.3 *Acid Value*

A proper knowledge and understanding of the changes associated with acid value of shea butter is necessary as it plays a role in the rancidity of the fat. Egan *et al*. (1985) explained that acid value of fat is the measure of the extent to which the glycerides in the oil have been decomposed by lipase or other actions.

Generally, the acid value of the shea butter studied was observed to increase with storage time (Figure. 18). The mean values of the butter were found to increase from 6.55–7.38 % and 6.55–8.20 % respectively for samples kept under room temperature and open air conditions during the three months storage period. Comparatively lower increases of 6.55-6.82 % were observed for the samples kept under refrigeration conditions during storage, indicating the influence of storage condition on the acid value of the butter during storage.

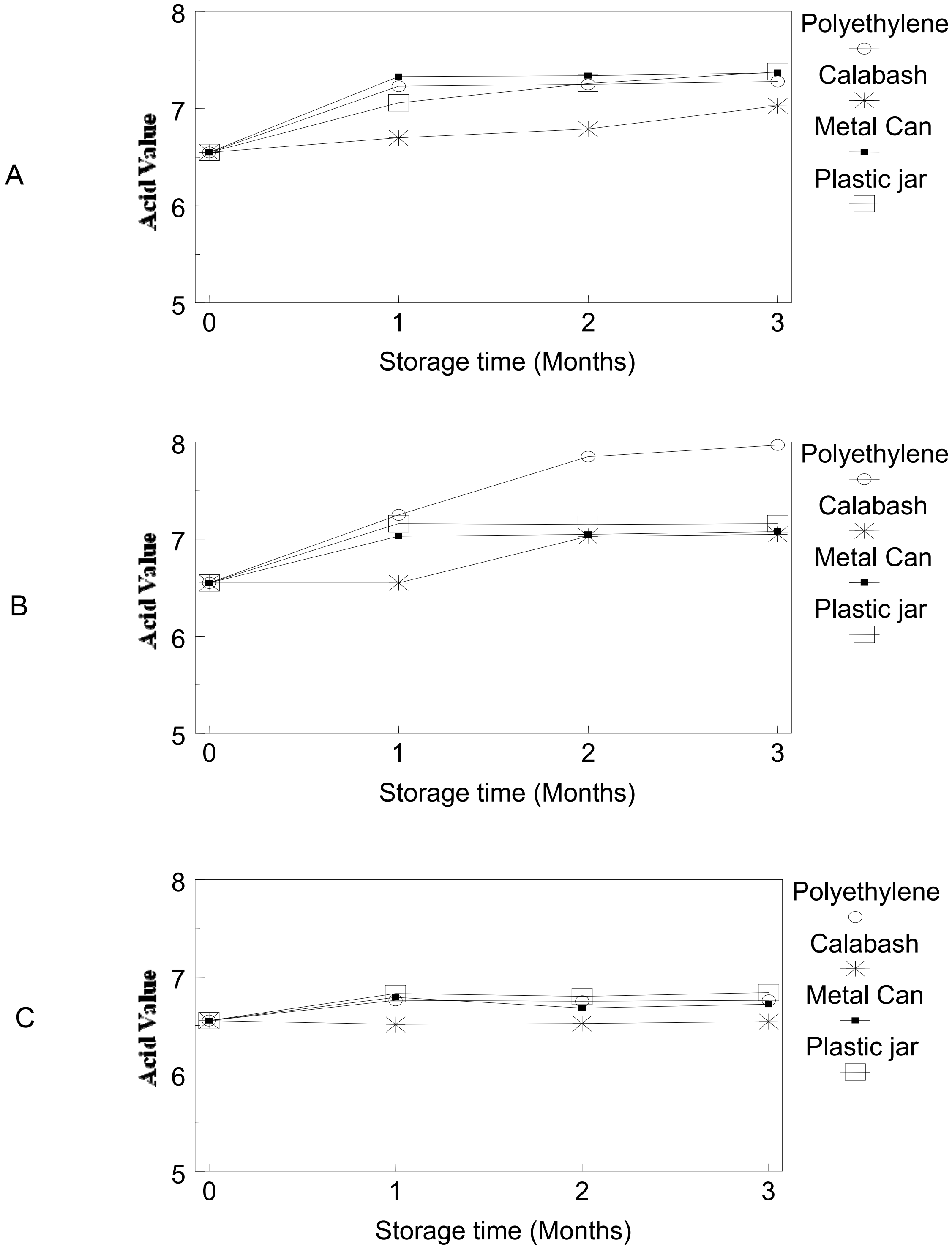

Figure 18. Effect of Storage Condition, Storage Time and Packaging Material on the Acid Value of Shea Butter (A: Room Temperature (26-31°C), B: Open Air (28-34°C), C: Refrigerator (4-7 °C) Conditions).

Source: From Author's Laboratory Work

The increases noted for the samples kept under open air and room temperature conditions might have been brought about by the influence of light in enhancing rancidity of fat (Egan et al., 1985), since those storage conditions exposes the sample to light. Storage under low temperature conditions is noted to slow the rate of change in the acid value of shea butter.

The packaging material used for the storage of the butter samples also influenced the trends in the acid value of the butter during storage. Rapid increases in acid value ranging from 6.55-8.2 % and 6.55-7.16 % were recorded for samples packaged in polyethylene bags and kept under open air and room temperature conditions during storage. This implies that samples packaged in polyethylene bags and plastic containers undergo rapid increases in acid value as compared to the other packaging materials due to the fact that the plastic container and the polyethylene bags are transparent and allows the penetration of light into the samples during storage. This suggests that shea butter can best be stored in metal cans and calabash kept under refrigerated conditions.

Analysis of variance conducted on the data showed that the storage time, storage condition and packaging material significantly affected ($p \leq 0.05$) the acid value of the shea butter (Table 16). Multiple range analysis on the ANOVA results further indicated that the significant effect noted with the packaging material was due to the higher values observed for the polyethylene bags whilst that of the storage condition was due to the storage of samples in open air conditions. However, a two-factor interaction between packaging material and storage time showed no significant effect ($p \leq 0.05$) on the acid value (Table 16). This implies that all the packaging materials used can effectively be employed for storing shea butter without any significant changes in acid value.

Table 16. Table of F-Values for Some Chemical Properties of Shea Butter

Process variable	Moisture	Free fatty acids	Acid value	Iodine value	Peroxide value
Storage time (ST)	6.364	19.701*	28.287*	12.876*	10.786*
Storage condition (SC)	9.871	15.706*	23.964*	8.537*	8.674*
Packaging material (PM)	38.862	7.734*	11.408*	5.659*	8.048*
SC x PM	8.647*	3.885*	3.618*	2.769*	4.352*
SC x ST	1.174	3.438*	3.540*	3.231	6.364*
PM x ST	4.567	0.972	1.686	2.632	2.452

*Significant at $p<0.05$

Source: From Author's Laboratory Analysis

4.4.4 *Iodine Value*

Iodine value is the measure of the degree of unsaturation of a particular oil or fat. It is the most useful and easily determined index for the identification of oils and their further placement in the respective groups. Egan *et al*. (1985) stated that the greater the degree of unsaturation (the higher the iodine value), the greater is the liability of the oil or fat to become rancid by oxidation. Therefore, quantitative changes in the iodine value of shea butter will presumably affect their storage quality.

Storage was generally observed to increase the iodine value of the shea butter samples (Figure 19). The study revealed that the rate of increase in the iodine value were slightly higher in the samples kept under room temperature and open air conditions than those kept under refrigerated conditions. Mean values ranging from 59.86 to 60.18 and 59.86 to 59.98 were noted for the samples kept under open air and room temperature conditions respectively whilst samples kept under refrigerated conditions increased from 59.86 to 59.90. Low temperature storage therefore reduces the rate of increase in the iodine value. This means that the rate of increase in the iodine value of shea butter is influenced by the temperature and time of storage. These increases in the iodine value of shea butter is attributed to the ability of the glycerides in the unsaturated fatty acids in shea butter to unite with a small amount of halogen thereby increasing its degree of unsaturation with consequential increase in iodine value. The type of packaging material used also influenced the iodine value of the samples during storage. However, the variations observed with the different packaging materials were not wide enough to affect the quality of the product.

Statistical analysis on the data indicated that the storage time, storage condition and packaging material had significant effect ($p \leq 0.05$) on the iodine value of the butter (Table 16). Multiple range analysis conducted on the ANOVA revealed that the significant differences observed with storage conditions was due to the higher rate of increases in iodine value during storage under open air conditions whereas those observed for the packaging material was brought about by the observed changes in the samples stored in polyethylene bags. This suggests that storage of shea butter in polyethylene bags under open air condition brings about rapid increases in iodine value thereby causing the deterioration of the butter. A two-factor interaction between packaging material and storage time showed no significant effect (Table 16, p. 117).

A

B

C

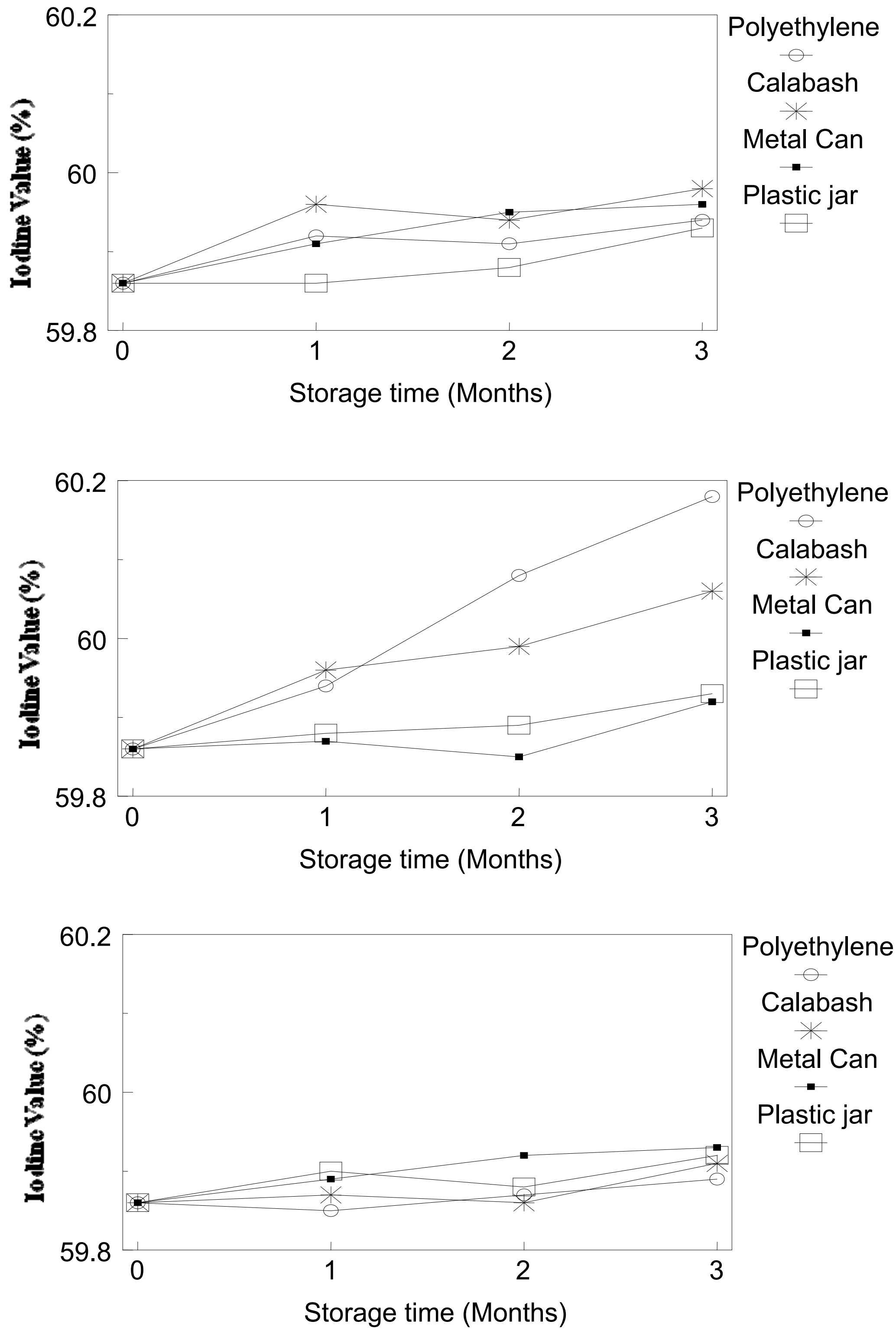

Figure 19. Effect of Storage Condition, Storage Time and Packaging Material on the Iodine Value of Shea Butter (A: Room Temperature (26-31°C), B: Open Air (28-34°C), C: Refrigerator (4-7 °C) Conditions).

Source: From Author's Laboratory Work

4.4.5 *Peroxide Value*

The peroxide value is a measure of the peroxides contained in the oil. During storage, peroxide formation is slow at first during an induction period which may vary from a few weeks to several months depending upon the type of fat or oil (Berger and Hamilton, 1995). There were generally increases in the peroxide value of the shea butter samples during the three months of storage (Figure 20). During storage, the rate of increase in the peroxide value were quite low during the first month in all the samples, which subsequently increased tremendously in the samples kept under open air and room temperature conditions than those kept under refrigerated conditions. Mean values observed during the three months storage period ranged between 8.24 to 11.40 mEq/kg and 8.24 to 10.46 mEq/kg for the samples kept under open air and room temperature conditions respectively. Comparatively lower values of 8.24 to 8.86 mEq/kg were observed in the samples kept under refrigerated conditions during the storage period. This explains that low temperature storage slows down the rate of increase in the peroxide value of shea butter. The slow rate of increase in the peroxide value of the samples during the first month of storage might have resulted from the induction period the fat undergoes during the first few weeks of storage as reported by Berger and Hamilton (1995).

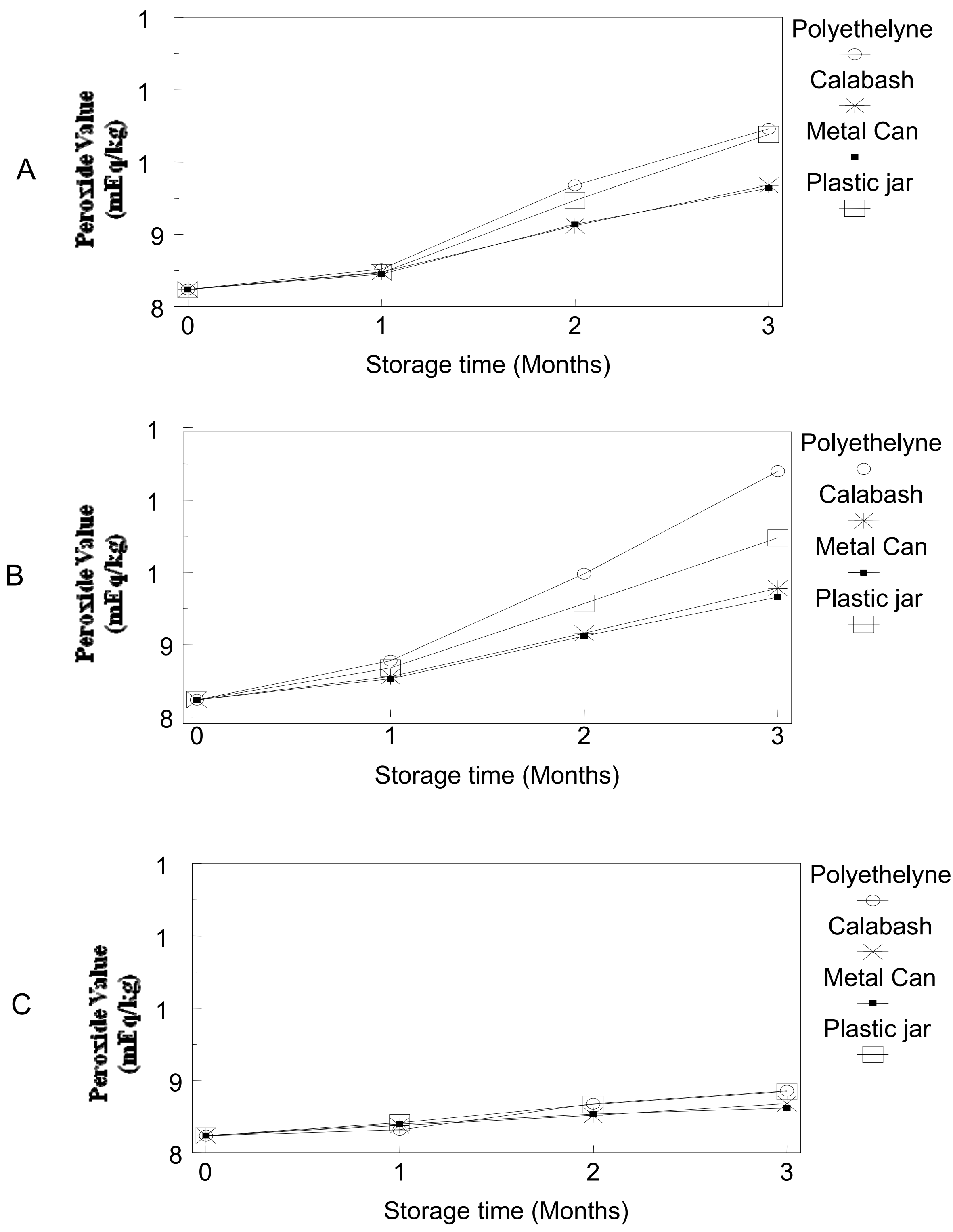

Figure 20. Effect of Storage Condition, Storage Time and Packaging Material on the Peroxide Value of Shea Butter (A: Room Temperature (26-31°C), B: Open Air (28-34°C), C: Refrigerator (4-7 °C) Conditions).

Source: From Author's Laboratory Work

However, the general increase in the peroxide value of shea butter recorded is suggested to have attributed to the oxidative rancidity of the fat during storage, resulting in increases of the peroxide value of the samples. It was as well observed that the type of packaging material used influenced the peroxide value of the samples during storage. Comparatively higher increases in peroxide value were noted for the samples packaged in polyethylene bags and plastic containers during the storage period (Figure 20). This observation is attributed to the fact that both the polyethylene bags and plastic containers are transparent and light, allowing some amount of air to get into contact with the sample resulting in oxidation. Egan et al. (1985) reported that the rancid state of fats begins to be noticeable when the peroxide value is between 20 and 40 mEq/kg. This means that even though the butter kept under room temperature and open air conditions undergo considerable increases in peroxide value, the degree of increase were not high enough to cause noticeable rancidity in the butter to affect the physical quality of the product. Low temperature storage as well as the storage of samples in metal cans and calabashes might be the best employable storage parameters to prolong the quality of the butter.

Analysis of variance conducted on the data showed that the storage time, storage condition and packaging material significantly affected ($p \leq 0.05$) the peroxide value of the shea butter (Table 16). Multiple range tests on the ANOVA showed that the significance effect observed in the storage time occurred after the second month in storage whilst that of the storage condition was caused by the open air storage of the samples. Likewise, the significant effect observed for packaging material was caused by the polyethylene bags.

4.4.6 *Saponification Value*

The results obtained from the storage studies indicate that the saponification value of the shea butter generally increased with storage time. Storage caused relatively rapid increases in saponification value of the butter kept under room temperature as compared to those kept under open air and refrigerated conditions. At room temperature conditions, the value increased tremendously within the first month of storage and maintained with the subsequent storage periods. However, consistent increasing levels in saponification value were observed for the samples kept under open air and refrigerated conditions till the end of the three months of storage (Figure 21). These increases in saponification value as observed during storage of the shea butter might have occurred as a result of the hydrolysis of the esters of fatty acids present in the butter resulting in increased glycerol formation and free fatty acids with consequential increases in saponification value of the butter. Egan *et al.* (1985) reported that the saponification value of butter fat is inversely proportional to the mean of the molecular weights of the fatty acids in the glycerides present. Decreases in the fatty acids of the butter due to hydrolysis during storage therefore leads to increased saponification value.

The different packaging material used for the storage of the butter did not have any influence on the saponification value of the samples with the exception of calabash and metal cans which seemingly reduced the saponification value of samples kept under open air and refrigerated conditions respectively. Statistical analysis conducted showed that storage time and storage condition significantly affected ($p \leq 0.05$) the saponification value of the shea butter. However, the packaging material used did not have any influence on the saponification value (Table 17).

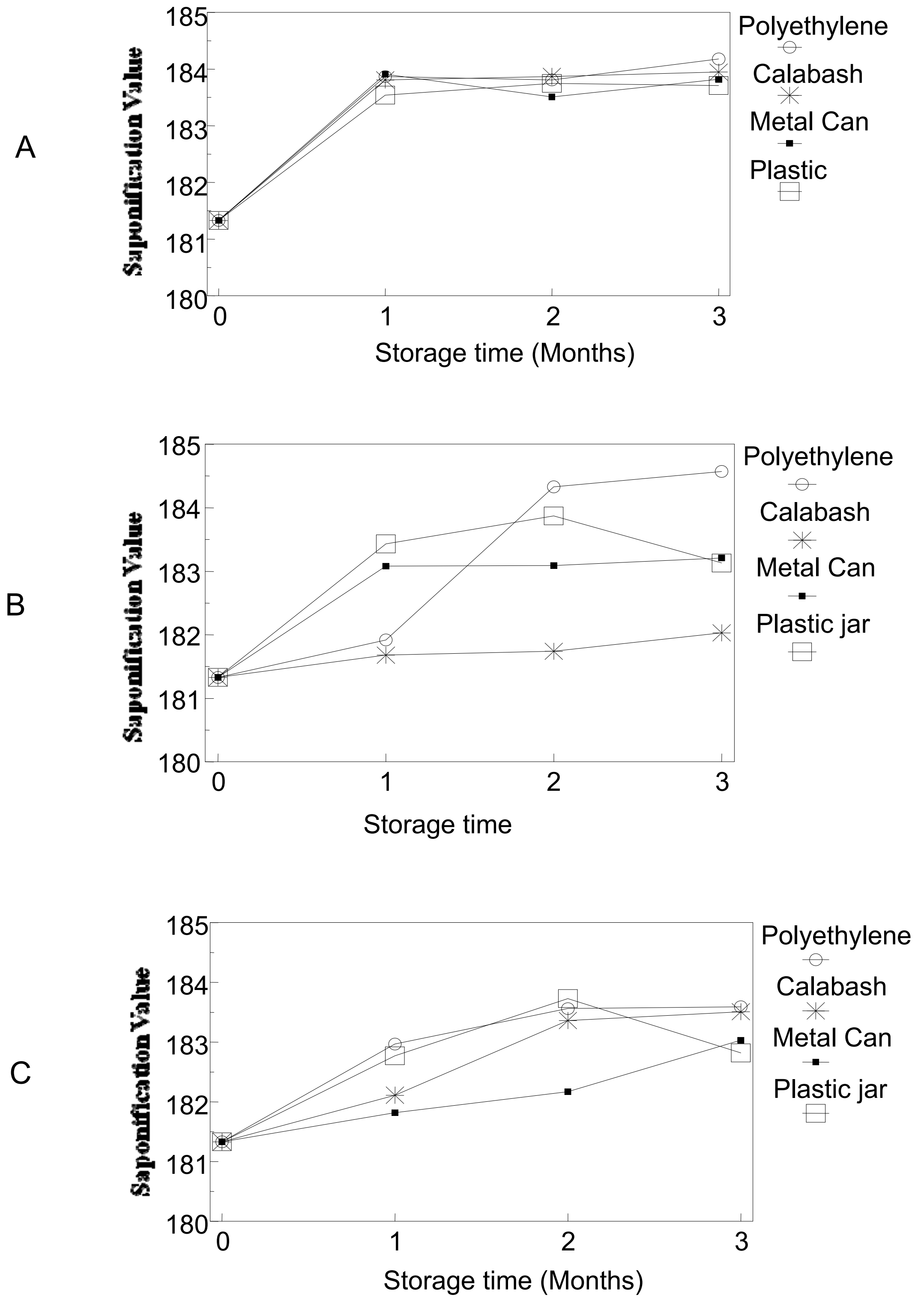

Figure 21. Effect of Storage Condition, Storage Time and Packaging Material on the Saponification Value of Shea Butter (A: Room Temperature (26-31°C), B: Open Air (28-34°C), C: Refrigerator (4-7 °C) Conditions).

Source: From Author's Laboratory Work

4.4.7 *Unsaponifiable Matter*

The unsaponifiable matter of fats denotes the material present in the fat which after saponification of the fat by caustic alkali and extraction by a suitable organic solvent remains non-volatile on drying at 80° C (Egan *et al.,* 1985). The unsaponifiable matter of the shea butter studied showed no major differences between the storage conditions under which the samples were kept. Generally, there were only slight increases in the unsaponifiable matter of the samples kept under room temperature conditions (Figure 22). The unsaponifiable matter of the samples increased slightly from 5.56-6.91 and 5.56-5.87 for the samples kept under room temperature and open air conditions respectively. Storage of the butter under refrigerated conditions did not cause any variation in the unsaponifiable matter of the samples.

Table 17. Table of F-Values for Saponification Value and Unsaponifiable Matter of Shea Butter

Process variable	Saponification value	Unsaponifiable matter
Storage time	36.004*	80.382
Storage condition	6.056*	73.143
Packaging material	3.716	3.580

*Significant at p<0.05

Source: From Author's Laboratory Analysis

Likewise, the type of packaging material used did not affect the unsaponifiable matter of the samples during storage. This observation suggests that during storage of the shea butter, there were no adulteration of the samples with regards to the addition of hydrocarbons, higher alcohols and sterols (cholesterol and phytosterol). Analysis of variance conducted on the data indicated that storage time, storage condition and packaging material had no significant effect (p≤0.05) on the unsaponifiable matter of the samples (Table 17).

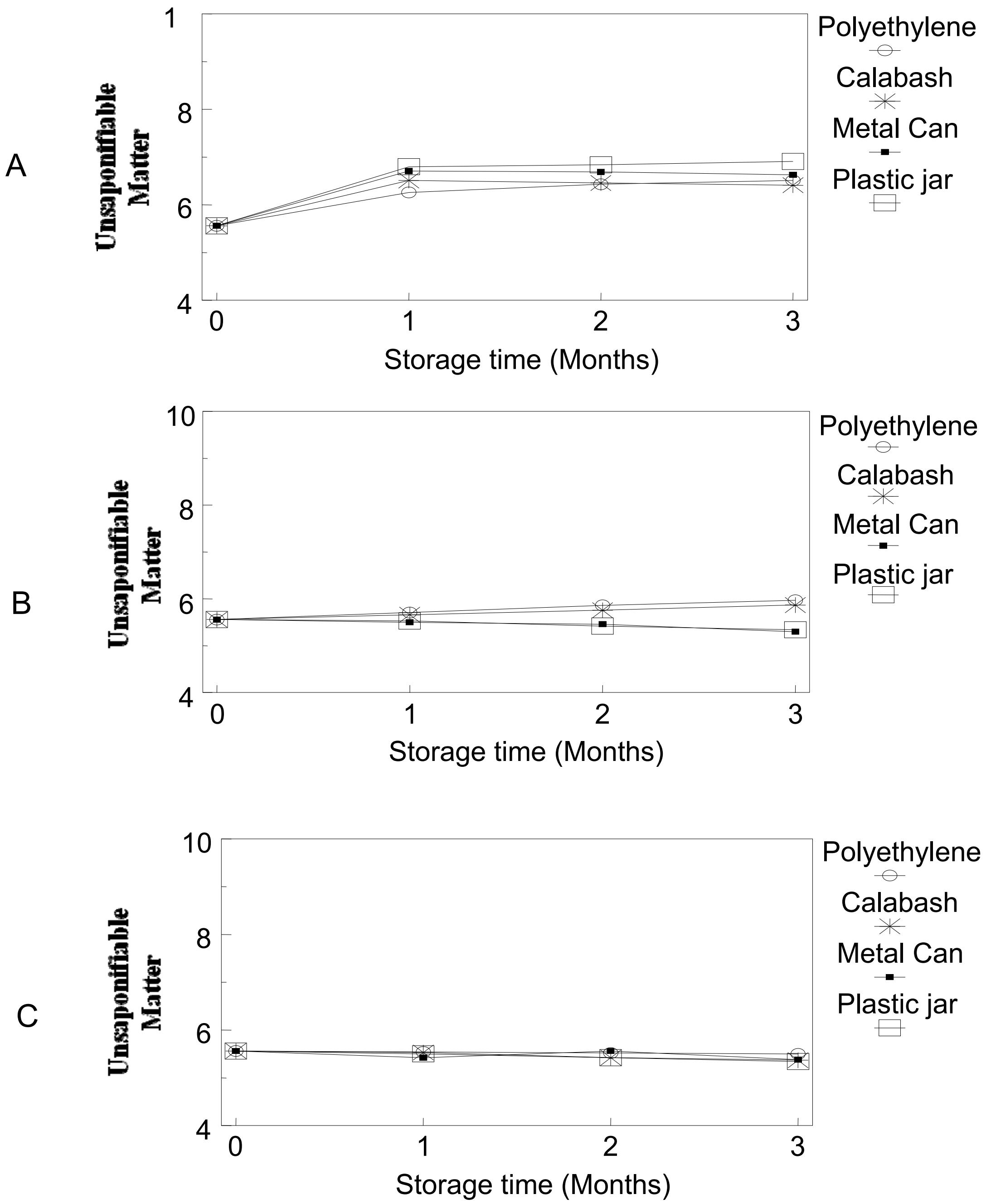

Figure 22. Effect of Storage Condition, Storage Time and Packaging Material on the Unsaponifiable Matter Content of Shea Butter (A: Room Temperature (26-31°C), B: Open Air (28-34°C), C: Refrigerator (4-7 °C) Conditions).
Source: From Author’s Laboratory Work

4.5 Physical Changes During Storage

Changes in physical properties associated with fats can be used to evaluate the quality of the fat. The physical properties (specific gravity, melting point and slip point) of the shea butter products under investigation were studied during storage to determine the storage behaviour of shea butter under different conditions and packaging materials.

4.5.1 *Specific Gravity*

The specific gravity of the shea butter studied was observed to decrease slightly with storage time (Figure 23). This trend was similar in the samples kept under the three storage conditions as well as the different packaging materials used during the storage period. The specific gravity of the butter decreased from 0.88-0.83 and 0.88-0.82 for the samples kept under room temperature and open air conditions respectively, whilst decreases of 0.88-0.81 were noted for the samples kept under refrigerated conditions. These observations suggest that the trends in the specific gravity of the samples were similar with the different conditions. However, the decreasing trend observed in the specific gravity of the butter during storage is suspected to be brought about by the increases in the saponification value and free fatty acids of the samples as a result of the respective hydrolytic and oxidative rancidity occurred in the butter during storage causing the specific weight of the butter to decrease. Egan *et al.* (1985) explained that the saponification value of butter fats is inversely proportional to the molecular weights of the fatty acids in the glycerides present. The type of packaging material used for the storage of the samples did not influence the specific gravity of the samples during the storage period (Figure 23).

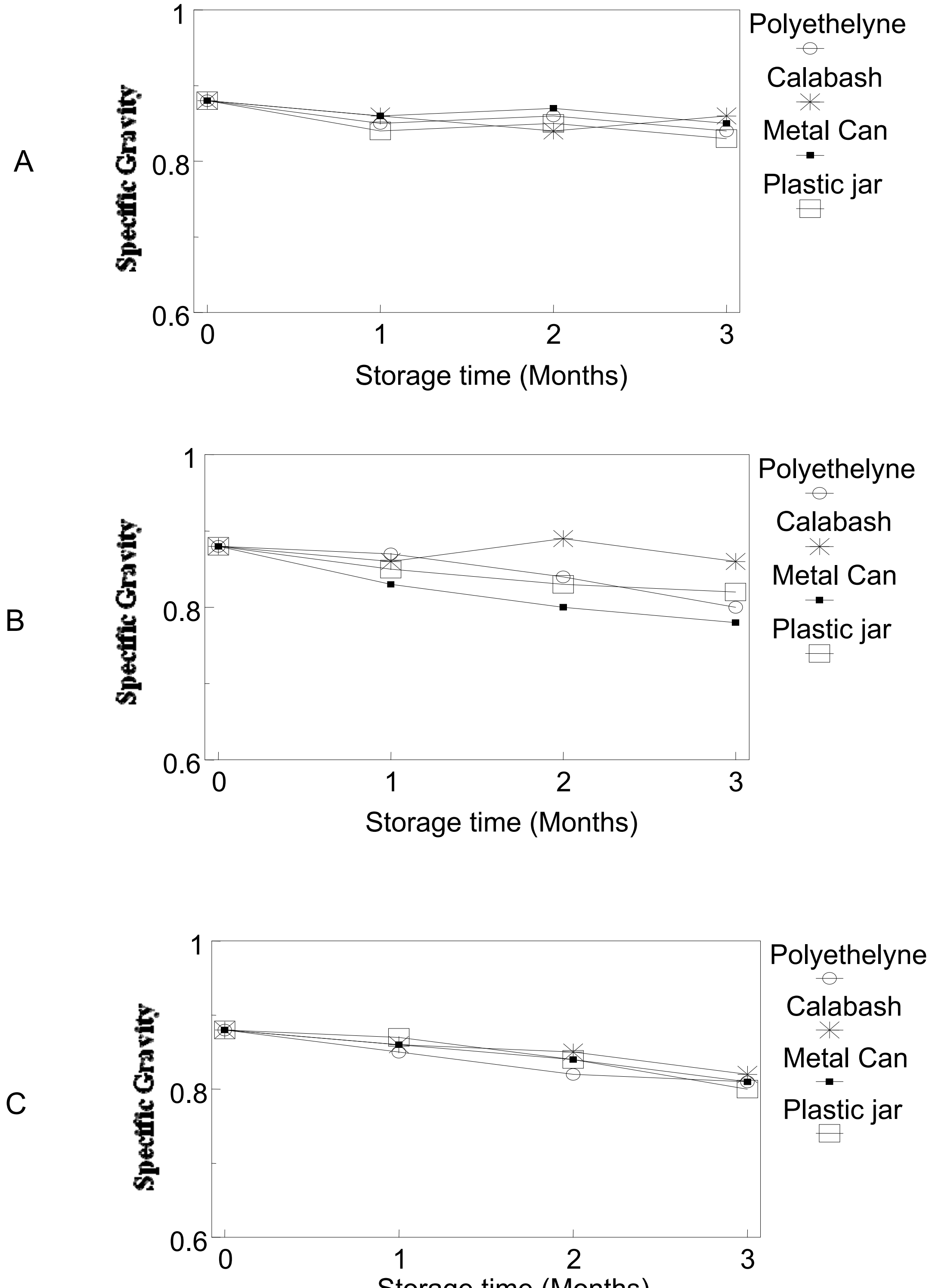

Figure 23. Effect of Storage Condition, Storage Time and Packaging Material on the Specific Gravity of Shea Butter (A: Room Temperature (26-31°C), B: Open Air (28-34°C), C: Refrigerator (4-7 °C) Conditions).

Source: From Author's Laboratory Work

This means that all the different packaging materials can be used to store shea butter without any major changes in specific gravity. Statistical analysis conducted on the data indicated that with the exception of storage time which had significantly affected the specific gravity of the samples, storage conditions and packaging material had no effect ($p<0.05$) on the specific gravity of the samples (Table 18).

4.5.2 *Melting Point*

The melting point of fats denotes the point at which the last trace of solid melts. It usually signifies the melting temperature of the highest melting component. Fennema (1976) explained that melting point data are useful for animal fats and processed fats but are of little value for vegetable oils since most of them are liquid at ambient temperatures. This index is of significance to shea butter for the reason that even though it is of a plant origin, its end-product and storage appearance is always in the solid state.

The melting point of the shea butter studied during the storage period showed no observable trend with storage time (Fig. 24). All the samples showed only slight fluctuations in melting point during the three months of storage, with samples kept under the different storage conditions. Similarly, the type of packaging material used for the storage of the samples did not influence the melting point of the samples with only slight observable variations in storage. ANOVA conducted on the data indicated that the storage time, storage condition and packaging material had no significant effect ($p\leq0.05$) on the melting point of the samples (Table 18).

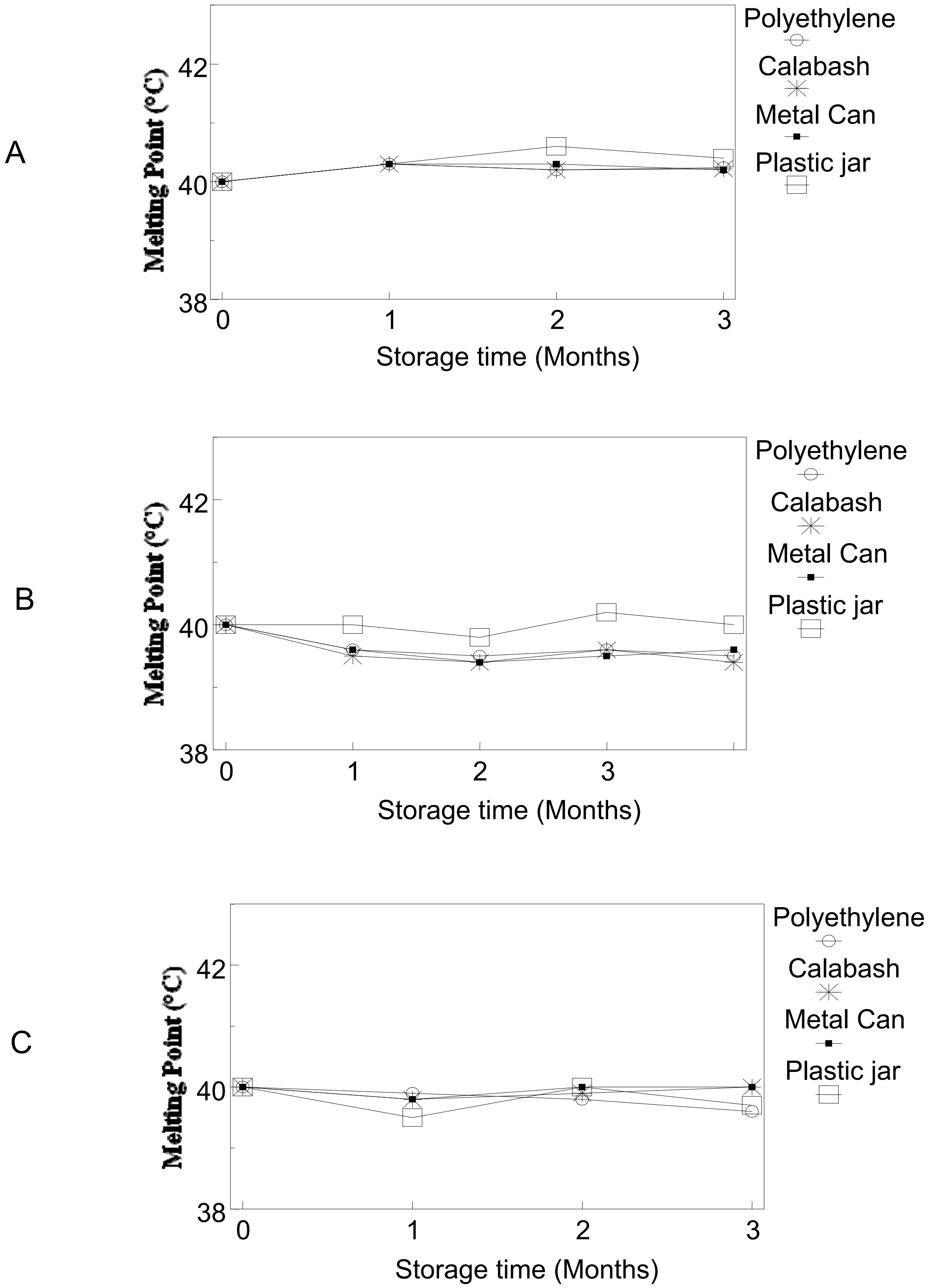

Figure 24. Effect of Storage Condition, Storage Time and Packaging Material on the Melting Point of Shea Butter (A: Room Temperature (26-31°C), B: Open Air (28-34°C), C: Refrigerator (4-7 °C) Conditions).

Source: From Author's Laboratory Work

This implies that storage of shea butter in the packaging materials used as well as the storage conditions does not influence the melting point to any appreciable level.

Table 18. Table of F-values for the physical properties of shea butter

Process variable	Specific gravity	Melting point	Slip point
Storage time	18.068*	1.975	600.903*
Storage condition	1.661	55.079	4.538
Packaging material	10.929	1.777	0.590

*Significant at $p<0.05$

Source: From Author's Laboratory Analysis

4.5.3 *Slip Point*

The results of the storage studies indicate that the slip point of the shea butter generally increased with storage time (Fig. 25). Storage caused slight increases in slip point of the butter kept under room temperature, open air and refrigerated conditions. At all the storage conditions, the slip point increased rapidly within the first month of storage which maintained with the subsequent storage periods. These increases in slip point as observed during storage of the shea butter might have occurred as a result of the chemical changes occurred in the samples during storage thereby increasing the slip point.

The different packaging material used for the storage of the butter did not have any influence on the slip point of the samples kept under room temperature, open air and refrigerated conditions. Statistical analysis conducted showed that storage time significantly affected ($p\leq0.05$) the slip point of the shea butter. However, the storage condition and packaging material used did not have any influence the slip point (Table 18).

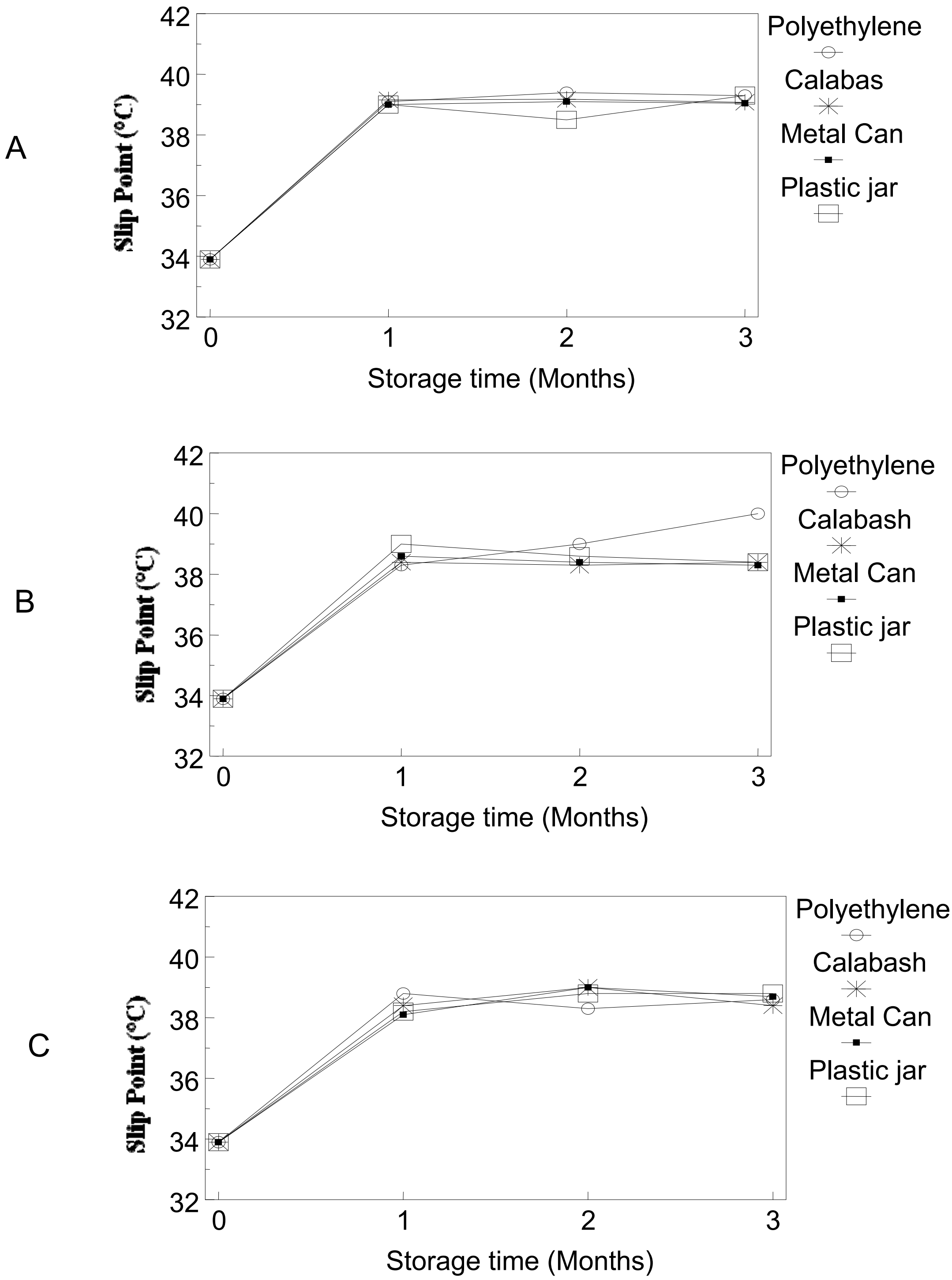

Figure 25. Effect of Storage Condition, Storage Time and Packaging Material on the Slip Point of Shea Butter (A: Room Temperature (26-31°C), B: Open Air (28-34°C), C: Refrigerator (4-7 °C) Conditions).

Source: From Author's Laboratory Work

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

1. Jatropha seeds were processed into bio-fuel, which served as an alternative oil substitute to power diesel engines used in shea butter extraction. The availability of Jatropha bio-fuel did help in achieving energy security in remote communities that were otherwise inaccessible and constantly short of regular supply of fossil fuels e.g. diesel and kerosene.

2. The study has demonstrated that with adequate training and the use of appropriate technology, rural illiterate women could efficiently extract oils to sustain their livelihoods.

3. More than three-quarters of shea butter producers studied in the communities were females between the ages of 40–70. The age-sex distribution therefore suggest that the greater number of shea butter producers are very old married females who are over 40 years and this will affect the trends of production with time if younger ones are not encouraged to engage in shea butter processing. The producers are also mostly illiterate farmers who had no formal education in their lifetime. Contrary to this, all the exporters had had formal education with 60% of them having up to tertiary education.

4. The existing and potential importing countries for shea butter are the United Kingdom, Japan, Netherlands and United States of America. No standard packaging regulation has been set out for the exportation of shea butter. The packaging materials

normally used for shea butter export are card boxes, metal drums, plastic containers and clipped wooden boxes. The exporters have however adjudged Card boxes and metal drums as the best packaging materials for shea butter export. The export quality specification set out for the export of shea butter states that the butter to be exported should be free from contamination and should be cream in colour. As well, moisture, free fatty acids and acid values should be between 1-6%.

5. Packaging of shea butter for the local market is done using the traditional calabash with the reason that it is cheap, available, easily transportable and it prevents the fat from melting during storage. Shea butter producers mainly store their products in order to find good market and prices for them, and the use of calabash for packaging shea butter for the local market retains the quality of the products for long periods of time with only minimal changes.

6. Changes in the chemical properties of the butter were observed during storage of the product under the different storage conditions and packaging materials. Storage caused slight increases in moisture content, free fatty acid, acid value, iodine value and peroxide value (8.24-10.64 mEq/kg) within the three months storage period. Products stored under open air (28-34°C) conditions generally significantly ($p \leq 0.05$) affected the chemical properties of the butter during storage even though the changes observed were not high enough to affect the exportable quality of the products whilst those stored under ambient (26-31°C) and refrigerated (4-7°C) conditions did not have significant effect on the chemical properties. No wide variation in physical properties were noted for the products during storage under the different storage conditions and packaging materials.

7. Storage of shea butter can be done using all the four different packaging materials studied. However, it is highly recommended that the products are kept under tropical ambient (26-31°C) and refrigerated conditions (4-7°C) during storage. The best condition for the storage of shea butter is refrigeration which maintains the quality of the product during prolonged stored periods. Storage of shea butter under open air (28-34°C) conditions allows for oxidative and hydrolytic rancidity which renders the products unsuitable for consumption after long storage periods.

5.2 Recommendations

Based on the findings of this study, the following recommendations are being made:

1. Further research need to be done to determine the yield levels and various costs involved in the cultivation, harvesting and processing of jatropha.

2. There is also the need for further studies to determine the effect of the jatropha plant on soils and to conduct ecological risk analysis to assess the impacts when the plant is cultivated on a large scale on arable lands instead of marginal lands.

3. Shea butter producers in the studied communities should be encouraged to form Shea Butter Producers Association and Co-operative Societies. This will make them be recognized and also enhance their chances of attracting credit facilities and other necessary support required to expand and boost shea butter production in Ghana.

4. The local authorities (government) of the studied communities should foster a closer working relationship between the producers, exporters as well as the local and international users of shea butter. This will facilitate a better information flow between the principal parties in the shea butter industry

5. The relevant government ministries should also provide more information and technical support to such associations or co-operative societies that intend to seek funding support from financial institutions. This will facilitate the procurement of

loans and equipments needed to increase shea butter production to meet the increasing demand by the local and international market.

6. Further work needs to be done to find out the factors that affect the changes in the chemical properties of the products during storage under open air (28-34°C) conditions and how they can be controlled in order to increase the storable conditions for shea butter after processing.

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APPENDIX 1.

THE DEVELOPMENT OF A SUITABLE PACKAGING SYSTEM FOR AN ENHANCED SHELF LIFE OF SHEA BUTTER.

<u>EXPORTER EVALUATION FORM:</u>

A. RESPONDENT DEMOGRAPHIC DATA:

1. Date:…………………… 2. Region……………………….

3. Town/Village……….. 4. Gender M/F

5. Marital status S/M/WIDOWED 6. Age…………………………

7. Religion
1. Christian 2. Moslem 3. Traditionalist 4. Other

8. Educational Status
1. Elementary 2. Secondary 3. Tertiary 4. Other

9. Which aspect of the shea butter trade are you involved in?

B. GENERAL PACKAGING AND STORAGE

10. Local name of product…………………………………………………

11. What packaging materials are being used: ………………….

12. Which of the following materials, in your opinion is the best for packaging shea butter?……………
    a. Aluminum foil laminate
    b. Plastic containers such as Polyethylene bags, jars, boxes, tubes, large drums and trays.
    c. Metal cans
    d. Glass jars etc.
    e. Calabash
    f. Give reasons.

    ……………………………………………………………………………
    …..……………………………………………………………………………

13. What is the unit weight of your packaged product?…………………………….
14. Why do you have a preference for that particular packaging?……..……………

…………………………………………………………………………..…..

15. Why do you package your product?
…………………………………………………………………………………………
……………………………………………..……………………………………………

16. a) Does contamination affect your product?……………………………………..
How?…………………………………………………………………………………………
….……………………………………………………………………………………………

17. What steps have you taken to solve the contamination?
……………………………………………..…………………………………………………
……………………………………………….…………………………………………………

18. How long do you keep the butter before exporting?
……………………………………………………………………………….……

19. Why do you store it?
…………………………………………………………………………………………
…………………………………………………………………………………………

20. Why this length of time (duration)?
…………………………………………………………..……………………
………………………………………………………………………..………..

21. Do you have any quality changes during storage?
……………………………………………………………………………..……….

22. If yes explain.
……………………………………………………………………………………..

23. What are they?
……………………………………………………………………………………..

24. List three major constraints you face in selecting appropriate packaging for your products.
………..………………………………………………………………………………
…………………………………………………………………………………………

25. To which country do you export the product?
b) Give reasons for your choice.
…………………………………..………………………………………………
……………………..…………………………………………………………………

26. What traditional methods are used for packaging shea butter?
…………………………………………………………………………………………
………………………………………………………………………………………..

27. What modern alternatives methods can be used?
……………………….………………………………………………………………
…………………………………………………………………………………………….

28. Do changes in temperature affect the quality of shea butter stored?
……………………………………………………………………………..……..

29. If yes explain.
……………………………………………………………………….……………………
……………………………………………………………………………………………….

30. What quality characteristics do you satisfy before exporting the butter?
………………………………………………………………………………………………
……………………………………………………..……………………………………

31. Is special packaging material required?
…………………………………….…………………………………………………
……………………………………………………………………………..…………

32. Where do you obtain your packaging material?
………………………………………………………………………………………………
………………………………………………………………………………………………

33. Name at least two aspects of your packaging which help in the marketing of your product.
……………..……………………………………………………………………………
…………………………….………………………………………………………………

34. Do you consider the following for selecting the best material?

ITEM	YES	NO
Resistance to oil and fat		
Permeability to gases		
Maximum filling temperature		
Colour, clarity and surface finish		
Is hand or special closing needed		
Is bulk packaging needed		
Suitability for contact with food		

APPENDIX 2.

THE DEVELOPMENT OF A SUITABLE PACKAGING SYSTEM FOR AN ENHANCED SHELF LIFE OF SHEA BUTTER.

PRODUCER EVALUATION FORM

RESPONDENT DEMOGRAPHIC DATA:

1. Date:…………………… 2. Region……………………….

3. Town/Village……….. 4. Gender M/F

5. Marital status S/M/WIDOWED 6. Age…………………………

7. Religion
1.Christian 2. Moslem 3. Traditionalist 4. Other

8. Educational Status
1. Elementary 2. Secondary 3. Tertiary 4. Other

9. Which aspect of the shea butter trade are you involved in?

B. GENERAL PACKAGING AND STORAGE

10. Local name of product……………………………………………………

11. What packaging materials are being used:………………….

12. Which of the following materials, in your opinion is the best for packaging shea butter?……………
   g. Aluminum foil laminate
   h. Plastic containers such as Polyethylene bags, jars, boxes, tubes, large drums and trays.
   i. Metal cans
   j. Glass jars etc.
   k. Calabash
   l. Give reasons.
   ……………………………………………………………………………
   …..…………………………………………………………………………
   ……… …………………………………………………………………..…

13. What is the unit weight of your packaged product?…………………………….

14. Why do you have a preference for that particular packaging?
……….………………………………………………………………………
………………..……………………………………………………………….
15. Why do you package your product?

…………………………………………………………………………………………
………………………………………………………..……………………………………
………………………………………………………..……………………………………

16. a) Does contamination affect your product?
……………………………………………………………………………………………..
How?………………………………………………………………………………………
….……………………………………………………………………………………
….……………………………………………………………………………………

17. What steps have you taken to solve the contamination?
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………

18. How long do you keep the product after processing?
…………………………………………………………………………………………

19. Why do you store it?
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………

20. a) How long do you store the individual product?
………………………………………………………………………………………….
b) Why this length of time (duration)?……………………………….…………..
………………………………………………………………………….
…………………………………………………………………………
…………………………………………………………………………

21. Do you have any quality changes during storage?
………………………………..……………………………………………………

22. If yes explain.
……………………………………………………………………………………………..
…………………………………………………………………………………………

23. What are they?
……………………………………………………………………………………………..

24. List three major constraints you face in selecting appropriate packaging for your products.………..…………………………………………………………………
…………………………………………………………………………………………
……………………………………..………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………

25. In what way do you use shea butter? (tick)

1) food (frying)
2) cream
3) soap
4) other (specify).

Give reasons for your choice.
………………………………….…………………………………………………
…………………...……………………………………………………………..

26. What traditional methods are used for packaging shea butter?
………………………………………………………………………………………
………………………………………………………………………………………

27. What modern alternatives methods can be used?
………………………………………………………………………………………
……………………………………………………………………………………….

28. Do changes in temperature affect the quality of shea butter stored?
……………………………………………………………………….……………………..

29. If yes explain.
……………………………………………………………………….………………
……………………………………………………………………………………….

30. How do you store the finished product before solidification?
………………………………………………………………………………………
……………………………………………………………………………………….
………………………………………………………………………………………

31. In what form is the packaging material obtained?
………………………………………………………………………………………
………………………………………………………………………………………

32. Where do you obtain your packaging material?
………………………………………………………………………………………
……………………………………………………………………………..…………
………………………………………………………………………………………

33. What are the quality characteristics needed in shea butter to be used as soap?
………………………………………………………………………………………..

34. Do you follow specific procedure for making the soap?
………………………………………………………..……………………………
……………………………………………………………………………………….

35. If yes, list the process.
……………………………………………………………………………………….
…………………..…………………………………………………………………

36. Name at least two aspects of your packaging which help in the marketing of your product.

……………..………………………………………………………………………………
……………………….……………………………………………………………………

37. Do you consider the following for selecting the best material?

ITEM	YES	NO
Resistance to oil and fat		
Permeability to gases		
Maximum filling temperature		
Colour, clarity and surface finish		
Is hand or special closing needed		
Is bulk packaging needed		
Suitability for contact with food		

Appendix 3. Analysis of Variance for Moisture

Source of variation	Sum of squares	d.f.	Mean square	F-ratio
MAIN EFFECTS	0.8085042	8	0.1010630	19.427
Storage condition (SC)	0.1027042	2	0.0513521	9.871
Packaging (PM)	0.6064833	3	0.2021611	38.862
Storage time (ST)	0.0993167	3	0.0331056	6.364
2-Factor Interactions	.5203250	21	.0247774	4.763
ST x PM	.2698792	6	.0449799	8.647
SC x ST	.0366458	6	.0061076	1.174
PM x ST	.2138000	9	.0237556	4.567
RESIDUAL	0.0936375	18	0.0052021	
TOTAL (CORR.)	1.4224667	47		

Appendix 4. Analysis of Variance for Free Fatty Acids

Source of variation	Sum of squares	d.f.	Mean square	F-ratio
MAIN EFFECTS	1.5947500	8	0.1993438	14.213
Storage condition (SC)	0.4404167	2	0.2202083	15.701
Packaging (PM)	0.3254250	3	0.1084750	7.734
Storage time (ST)	0.8289083	3	0.2763028	19.701
2-Factor Interactions	.7389917	21	.0351901	2.509
ST x PM	.3269500	6	.0544917	3.885
SC x ST	.2893167	6	.0482194	3.438
PM x ST	.1227250	9	.0136361	.972
TOTAL (CORR.)	2.5861917	47		

Appendix 5. Analysis of Variance for Acid Value

Source of variation	Sum of squares	d.f.	Mean square	F-ratio
MAIN EFFECTS	4.4834792	8	0.5604349	20.877
Storage condition (SC)	1.2866292	2	0.6433146	23.964
Packaging (PM)	0.9187333	3	0.3062444	11.408
Storage time (ST)	2.2781167	3	0.7593722	28.287
2-Factor Interactions	1.560475	21	.0247774	2.763
ST x PM	.5828042	6	.0449799	3.618
SC x ST	.5766458	6	.0061076	3.540
PM x ST	.4087000	9	.0237556	1.686
TOTAL (CORR.)	6.5271667	47		

Appendix 6. Analysis of Variance for Iodine Value

Source of variation	Sum of squares	d.f.	Mean square	F-ratio
MAIN EFFECTS	4.4834792	8	0.5604349	20.877
Storage condition (SC)	1.2866292	2	0.6433146	23.964
Packaging (PM)	0.9187333	3	0.3062444	11.408
Storage time (ST)	2.2781167	3	0.7593722	28.287
2-Factor Interactions	.6303250	21	.0247774	3.633
ST x PM	.2628792	6	.0449799	5.697
SC x ST	.0325458	6	.0061076	2.274
PM x ST	.48138000	9	.0237556	4.257
TOTAL (CORR.)	6.5271667	47		

Appendix 7. Analysis of Variance for Peroxide Value

Source of variation	Sum of squares	d.f.	Mean square	F-ratio
MAIN EFFECTS	89.174025	8	11.146753	224.772
Storage condition (SC)	76.682579	2	38.341290	773.143
Packaging (PM)	0.532640	3	0.177547	3.580
Storage time (ST)	11.958806	3	3.986269	80.382
2-Factor Interactions	.2003250	21	.0241874	3.833
ST x PM	.2848792	6	.0473799	6.647
SC x ST	.0242458	6	.0061076	3.154
PM x ST	.2138074	9	.0247556	4.592
TOTAL (CORR.)	128.17635	47		

Appendix 8. Analysis of Variance for Saponification Value

Source of variation	Sum of squares	d.f.	Mean square	F-ratio
MAIN EFFECTS	8.0238958	8	0.0829870	10.289
Storage condition (SC)	4.0408792	2	0.0304396	3.661
Packaging (PM)	2.0086750	3	0.0028917	10.948
Storage time (ST)	0.5143417	3	0.2044806	19.068
2-Factor Interactions	10.808510	21	.5247774	1.763
ST x PM	2.2698792	6	.3449799	1.366
SC x ST	4.0366458	6	.6061076	2.313
PM x ST	4.2138000	9	.4 237556	1.650
TOTAL (CORR.)	0.0483917	47		

Appendix 9. Analysis of Variance for Unsaponifiable Matter

Source of variation	Sum of squares	d.f.	Mean square	F-ratio
MAIN EFFECTS	89.174025	8	11.146753	224.772
Storage condition (SC)	76.682579	2	38.341290	773.143
Packaging (PM)	0.532640	3	0.177547	3.580
Storage time (ST)	11.958806	3	3.986269	80.382
2-Factor Interactions	.5535342	21	1.247774	26.992
ST x PM	.2698792	6	.0449799	7.431
SC x ST	.0366458	6	.0061076	85.990
PM x ST	.2138000	9	.0237556	.700
TOTAL (CORR.)	118.17635	47		

Appendix 10. Analysis of Variance for Specific Gravity

Source of variation	Sum of squares	d.f.	Mean square	F-ratio
MAIN EFFECTS	0.0238958	8	0.0029870	11.289
Storage condition (SC)	0.0008792	2	0.0004396	1.661
Packaging (PM)	0.0086750	3	0.0028917	10.929
Storage time (ST)	0.0143417	3	0.0047806	18.068
2-Factor Interactions	.01795207	21	.0009974	3.552
ST x PM	.01026592	6	.00140799	6.606
SC x ST	.00637458	6	.00612076	2.060
PM x ST	.00538320	9	.00062356	2.509
TOTAL (CORR.)	0.0483917	47		

Appendix 11. Analysis of Variance for Melting Point

Source of variation	Sum of squares	d.f.	Mean square	F-ratio
MAIN EFFECTS	1.5310417	8	0.1913802	15.177
Storage condition (SC)	1.3890792	2	0.6945396	55.079
Packaging (PM)	0.0672396	3	0.224132	1.777
Storage time (ST)	0.0747229	3	0.0249076	1.975
2-Factor Interactions	.93252530	21	.0247774	3.522
ST x PM	.30766982	6	.0449799	4.066
SC x ST	.54530358	6	.0061076	7.204
PM x ST	.08210800	9	.0237556	.705
TOTAL (CORR.)	2.6907479	47		

Appendix 12. Analysis of Variance for Slip Point

Source of variation	Sum of squares	d.f.	Mean square	F-ratio
MAIN EFFECTS	214.90101	8	26.862626	226.695
Storage condition (SC)	1.07558	2	0.537790	4.538
Packaging (PM)	0.20987	3	0.069958	0.590
Storage time (ST)	213.61556	3	71.205185	600.903
2-Factor Interactions	1.809550	21	.0247774	.727
ST x PM	.5969592	6	.0449799	.841
SC x ST	.6240368	6	.0061076	.879
PM x ST	.5867213	9	.0237556	.550
TOTAL (CORR.)		47		

Appendix 13. Changes in Moisture Content During Storage

Storage Condition	Packaging material	Storage time (Months)			
		0	1	2	3
Room temperature (26-31°C)	Polyethylene	0.01	0.04	0.06	0.07
	Calabash	0.01	0.03	0.05	0.06
	Metal can	0.01	0.01	0.02	0.03
	Plastic	0.01	0.02	0.02	0.03
Open air (28-34°C)	Polyethylene	0.01	0.06	0.05	0.08
	Calabash	0.01	0.04	0.04	0.06
	Metal can	0.01	0.01	0.02	0.02
	Plastic	0.01	0.02	0.03	0.02
Refrigeration (4-7°C)	Polyethylene	0.01	0.02	0.03	0.03
	Calabash	0.01	0.03	0.04	0.05
	Metal can	0.01	0.02	0.02	0.03
	Plastic	0.01	0.02	0.03	0.04

Mean values (%) of replicates

Appendix 14. Changes in Free Fatty Acids During Storage

Storage Condition	Packaging material	Storage time (Months)			
		0	1	2	3
Room temperature (26-31°C)	Polyethylene	3.29	3.86	3.91	4.08
	Calabash	3.29	3.38	3.54	3.56
	Metal can	3.29	3.35	3.59	3.92
	Plastic	3.29	3.38	3.37	3.52
Open air (28-34°C)	Polyethylene	3.29	3.74	4.14	4.86
	Calabash	3.29	3.53	3.56	3.76
	Metal can	3.29	3.70	3.78	3.87
	Plastic	3.29	3.38	3.58	3.61
Refrigeration (4-7°C)	Polyethylene	3.29	3.39	3.41	3.42
	Calabash	3.29	3.27	3.28	3.27
	Metal can	3.29	3.44	3.43	3.44
	Plastic	3.29	3.41	3.42	3.42

Mean values of replicates

Appendix 15. Changes in Acid Value During Storage

Storage Condition	Packaging material	Storage time (Months)			
		0	1	2	3
Room temperature (26-31°C)	Polyethylene	6.55	7.23	7.25	7.28
	Calabash	6.55	6.70	6.79	7.03
	Metal can	6.55	7.33	7.34	7.37
	Plastic	6.55	7.06	7.26	7.38
Open air (28-34°C)	Polyethylene	6.55	7.25	7.85	7.97
	Calabash	6.55	6.56	7.03	7.05
	Metal can	6.55	7.03	7.05	7.08
	Plastic	6.55	7.16	7.15	7.16
Refrigeration (4-7°C)	Polyethylene	6.55	6.76	6.75	6.76
	Calabash	6.55	6.51	6.52	6.54
	Metal can	6.55	6.79	6.68	6.72
	Plastic	6.55	6.83	6.8	6.84

Mean values of replicates

Appendix 16. Changes in Iodine Value During Storage

Storage Condition	Packaging material	Storage time (Months)			
		0	1	2	3
Room temperature (26-31°C)	Polyethylene	59.86	59.92	59.91	59.94
	Calabash	59.86	59.96	59.94	59.98
	Metal can	59.86	59.91	59.95	59.96
	Plastic	59.86	59.86	59.88	59.93
Open air (28-34°C)	Polyethylene	59.86	59.94	60.08	60.18
	Calabash	59.86	59.96	59.99	60.06
	Metal can	59.86	59.87	59.85	59.92
	Plastic	59.86	59.88	59.89	59.93
Refrigeration (4-7°C)	Polyethylene	59.86	59.85	59.87	59.89
	Calabash	59.86	59.87	59.86	59.91
	Metal can	59.86	59.89	59.92	59.93
	Plastic	59.86	59.90	59.88	59.92

Mean values of replicates

Appendix 17. Changes in Peroxide Value During Storage

Storage Condition	Packaging material	Storage time (Months)			
		0	1	2	3
Room temperature (26-31°C)	Polyethylene	8.24	8.52	9.68	10.46
	Calabash	8.24	8.48	9.12	9.68
	Metal can	8.24	8.45	9.14	9.64
	Plastic	8.24	8.47	9.47	10.38
Open air (28-34°C)	Polyethylene	8.24	8.78	9.98	11.4
	Calabash	8.24	8.56	9.16	9.78
	Metal can	8.24	8.53	9.12	9.66
	Plastic	8.24	8.68	9.57	10.48
Refrigeration (4-7°C)	Polyethylene	8.24	8.32	8.68	8.86
	Calabash	8.24	8.38	8.52	8.68
	Metal can	8.24	8.4	8.54	8.62
	Plastic	8.24	8.42	8.67	8.85

Mean values of replicates

Appendix 18. Changes in Saponification Value During Storage

Storage Condition	Packaging material	Storage time (Months)			
		0	1	2	3
Room temperature (26-31°C)	Polyethylene	181.33	183.87	183.81	184.18
	Calabash	181.33	183.81	183.87	183.95
	Metal can	181.33	183.91	183.51	183.82
	Plastic	181.33	183.54	183.75	183.71
Open air (28-34°C)	Polyethylene	181.33	181.92	184.33	184.57
	Calabash	181.33	181.68	181.74	182.03
	Metal can	181.33	183.08	183.09	183.21
	Plastic	181.33	183.43	183.87	183.13
Refrigeration (4-7°C)	Polyethylene	181.33	182.97	183.56	183.59
	Calabash	181.33	182.11	183.36	183.51
	Metal can	181.33	181.82	182.17	183.03
	Plastic	181.33	182.77	183.73	182.82

Mean values of replicates

Appendix 19. Changes in Unsaponifiable Matter During Storage

Storage Condition	Packaging material	Storage time (Months)			
		0	1	2	3
Room temperature (26-31°C)	Polyethylene	5.56	6.26	6.43	6.51
	Calabash	5.56	6.51	6.46	6.41
	Metal can	5.56	6.71	6.69	6.63
	Plastic	5.56	6.8	6.84	6.91
Open air (28-34°C)	Polyethylene	5.56	5.71	5.86	5.97
	Calabash	5.56	5.66	5.76	5.87
	Metal can	5.56	5.5	5.46	5.3
	Plastic	5.56	5.53	5.42	5.34
Refrigeration (4-7°C)	Polyethylene	5.56	5.54	5.52	5.5
	Calabash	5.56	5.53	5.42	5.37
	Metal can	5.56	5.42	5.56	5.38
	Plastic	5.56	5.5	5.42	5.34

Mean values of replicates

Appendix 20. Changes in Specific Gravity During Storage

Storage Condition	Packaging material	Storage time (Months)			
		0	1	2	3
Room temperature (26-31°C)	Polyethylene	0.88	0.85	0.86	0.84
	Calabash	0.88	0.86	0.84	0.86
	Metal can	0.88	0.86	0.87	0.85
	Plastic	0.88	0.84	0.85	0.83
Open air (28-34°C)	Polyethylene	0.88	0.87	0.84	0.8
	Calabash	0.88	0.86	0.89	0.86
	Metal can	0.88	0.83	0.80	0.78
	Plastic	0.88	0.85	0.83	0.82
Refrigeration (4-7°C)	Polyethylene	0.88	0.85	0.82	0.81
	Calabash	0.88	0.86	0.85	0.82
	Metal can	0.88	0.86	0.84	0.81
	Plastic	0.88	0.87	0.84	0.80

Mean values of replicates

Appendix 21. Changes in Melting Point During Storage

Storage Condition	Packaging material	Storage time (Months)			
		0	1	2	3
Room temperature (26-31°C)	Polyethylene	40	40.3	40.2	40.24
	Calabash	40	40.3	40.2	40.22
	Metal can	40	40.3	40.3	40.2
	Plastic	40	40.4	40.6	40.4
Open air (28-34°C)	Polyethylene	40	39.6	39.5	39.6
	Calabash	40	39.5	39.4	39.6
	Metal can	40	39.6	39.4	39.5
	Plastic	40	40.0	39.8	40.2
Refrigeration (4-7°C)	Polyethylene	40	39.9	39.8	39.6
	Calabash	40	39.8	39.9	40.0
	Metal can	40	39.8	40.0	40.0
	Plastic	40	39.5	40.0	39.7

Mean values (°C) of replicates

Appendix 22. Changes in Slip Point During Storage

Storage Condition	Packaging material	Storage time (Months)			
		0	1	2	3
Room temperature (26-31°C)	Polyethylene	33.9	39.1	39.4	39.3
	Calabash	33.9	39.16	39.18	39.08
	Metal can	33.9	39.0	39.1	39.05
	Plastic	33.9	39.0	38.5	39.3
Open air (28-34°C)	Polyethylene	33.9	38.3	39	40
	Calabash	33.9	38.4	38.3	38.4
	Metal can	33.9	38.6	38.4	38.3
	Plastic	33.9	39.0	38.6	38.4
Refrigeration (4-7°C)	Polyethylene	33.9	38.8	38.3	38.6
	Calabash	33.9	38.4	39.0	38.4
	Metal can	33.9	38.1	39.0	38.7
	Plastic	33.9	38.2	38.8	38.8

Mean values (°C) of replicates