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Faculty of Tropical AgriSciences

Technology of Production of Shea Butter and its Influence on Economic Efficiency in Ghana

MASTER'S THESIS

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Declaration

I hereby declare that I have done this thesis entitled "Technology of Production of Shea Butter and its Influence on Economic Efficiency in Ghana" independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague, 22/04/ 2023

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Abstract

The shea nut, described as "women's gold," is an understudied non-timber forest product found primarily in the semiarid regions of Africa. In regions where shea is grown, women primarily engage in processing shea kernels into shea butter, which has numerous commercial and industrial applications. Since shea processing has not received much attention in the academic literature, the purpose of this study was to answer several questions that would fill in some of the gaps while also bringing attention to the shea tree and the various processes involved in the preparation of shea butter. Specifically, the study examined the efficiencies of the modern and indigenous technologies used in shea butter processing, the applications of the waste generated during production, the challenges of production, the profitability of shea processing, and the value-added activities. Quantitative research methods and a literature review were utilised to investigate these issues. The quantitative methods comprised most of the study, with data collected through the administration of questionnaires to 103 processors in Ghana's northern region. Both descriptive and inferential statistics were utilised to analyse the data. The literature review specifically addressed the question regarding the uses of shea waste.The results showed that the extraction rate of shea butter using modern technologies is 40.21%, while the extraction rate using indigenous technologies is 34.85%. The results of regression analysis showed that the use of modern technologies, a dummy variable, increases the extraction rate by 5.357 units more than the use of traditional technologies, and this difference is statistically significant (P =.001). Regarding profitability analysis (return on investment), it was observed that processors who employ modern technologies earn approximately 10% more profit per unit of money (GH 1) invested than those who use only indigenous technologies. It was also determined that the use of modern technology resulted in approximately GH 62 more in gross margin than indigenous technology, which was significant (P =.001).A review of the literature revealed that there have been very few studies on the uses of shea butter waste; four uses were identified in the following fields: energy, poultry feed, brickmaking, and soil nutrient improvement. The main challenges of production ranked by processors included cost of kernels, firewood, health risks, and access to finance. In terms of value addition, only one activity was discovered: the use of a local plant extract to give shea butter a yellow hue rather than the usual grey colour. Given the massive amount of waste generated by shea butter processing and the environmental impact this has, the study recommended and elaborated on the use of shea butter waste for biogas production in Ghana.

Keywords: shea butter; indigenous technology; modern technology; profitability; biogas; Ghana

Table of Contents

List of Figures

List of Tables

1 Introduction

It has become important to empower women and break down the socio-economic and legal barriers that prevent them from participating in the development of their countries, as it helps create a thriving environment for all citizens and enables women to contribute to their fullest potential (Lohani & Aburaida 2017; Völker & Doneys 2021). Yet, evidence from sub-Saharan Africa and other developing countries indicates that women are disempowered and often face inequalities, especially within the rural areas (The World Bank 2012; African Development Bank 2016; Klasen 2018). Such high levels of disempowerment affect not only the woman, but also have negative implications for her family/household, community, and country (The World Bank 2012; Anderson et al. 2020).

For instance, gender inequality has been linked to decreased general health and wellbeing of women, decreased family satisfaction, and increased rates of conflicts (Cerrato & Cifre 2018). In addition, estimates point out that such inequalities have led to 95 Billion USD in costs per year for sub-Saharan Africa (UNDP 2016). Women therefore continue to face unequal access to resources and are economically disadvantaged in rural areas, although they produce a significant proportion of food, are highly involved in agriculture, and form over half of the world's population (Ankrah et al. 2020; Glazebrook et al. 2020; Fonjong & Gyapong 2021). This calls for an examination into the various ways through which women, especially those in rural areas, can be empowered within sub-Saharan Africa (Grantham et al. 2021).

Among the ways to empower the marginalised and poor in sub-Saharan Africa, who also tend to be women, is empowerment through the agricultural sector (World Bank 2013). In 2014, agriculture employed about 78 per cent of the world's poor (World Bank 2014), and continues to be the leading employer of persons in sub-Saharan Africa (Jayne et al. 2017). It is therefore a great avenue not only for empowerment, but also for making a living, reducing poverty, improving food security, and improving wellbeing especially for rural dwellers who form the majority of persons in agriculture (World Bank 2013; Grantham et al. 2021). Given the right investment in the sector, the fertile lands in sub-Saharan Africa would have the potential to feed its populace and the world.

Investing in agriculture could be achieved from different angles. Governments may target the livelihoods based on context, an instance of which is the focus of the Ghanaian government on production of cocoa in Southern Ghana (Peprah 2019), and Shea nut in Northern Ghana (Laube et al. 2017). The choice of these crops is not solely based on their profitability, but also depends on how they thrive within the various climatic conditions. Other policies in Ghana may target different segments of the population within various livelihood options. One of the more common targets has been women in agriculture, yet the Food and Agriculture Organisation (FAO) and the Economic Community of West African States (ECOWAS) report that Ghana is yet to achieve holistic agricultural development because policies fail to improve the livelihoods of women in agriculture (FAO & ECOWAS 2018). It is also evident that even with the investment in Shea production in Northern Ghana, which is predominantly rural, the region remains the poorest in the country (Yaro & Hesselberg 2010; Ghana Statistical Service 2015), and this calls for a re-examination into the Shea industry in Ghana.

The Shea industry in Ghana has been booming over the past decades (Hatskevich et al. 2011; Abdul-Moomin et al. 2016; Hatzenbuehler 2019), with majority of the trees found in Upper West and East, as well as Northern, Savannah and North East Regions of Ghana (Hatskevich et al. 2011). As these regions are predominantly rural, women tend to depend on Shea nut as a source of income to improve wellbeing and reduce vulnerability (Laube 2015; Kent 2017). This is because, the job of gathering and processing Shea nuts is exclusively given to the women (Kent 2017; Laube et al. 2017). In addition, the Shea tree could contribute to food security (Mohammed et al. 2013; Nguekeng et al. 2021), as it ripens in the season of lean food production. Shea products also have health benefits, and as such there is a high demand for it (Sikpaam et al. 2019).

Based on the increasing potential of the Shea Tree, various organisations have attempted to initiate Shea projects, particularly with the purpose of improving livelihoods and empowering women in Shea processing. These include the Northern Province of the Catholic Church in collaboration with the Japan International Cooperation Agency (JICA), as well as the project by United Nations Development Fund for Women (UNIFEM) (Abujaja et al. 2014). These organisations, combined, have sought to increase and improve production and processing methods of women through knowledge and skill acquisition, as well as training programmes and provision of processing plants for modern methods of Shea processing (Abujaja et al. 2014). Despite these, production cannot meet local and international demands (Abujaja et al. 2014) and it has become important to examine the current processing techniques available and used by the women

(Agúndez et al. 2019) to understand their efficiencies. However, a review of the literature suggests that a comprehensive analysis of the efficiencies of these new technologies and production methods relative to the indigenous technologies are lacking. Considering this context, this study seeks to examine the relationships between modern and indigenous technologies and the production of shea butter in northern Ghana.

1.1 Problem statement

The goal to reduce, if not eliminate, poverty in developing countries can be attained with the right policies and investments put in place for the poor. In Ghana, the poorest are often in rural areas, and include women in agriculture (FAO & ECOWAS 2018). In the poverty profile of Ghana, Northern Ghana (made of Northern, North East, Savannah, Upper East and Upper West Regions) happen to the home of the poorest and contribute about 75 per cent to total poverty in the country (GSS 2018). Estimates indicate that over 900,000 women are involved in processing 130,000 tonnes of kernel in Northern Ghana (Anafo 2016; SNV 2018). Considering that the Shea industry employs a large proportion of the women in these areas, increase in output and income could economically empower the women as they are in charge of gathering and processing Shea fruits (Kent 2017; Laube et al. 2017).

Researchers and practitioners have attempted to explore the various ways to boost production among women involved in shea processing in sub-Saharan Africa (Matanmi et al. 2010; Akinsokeji et al. 2017; Abdul-Mumeen et al. 2019; Agúndez et al. 2019) and in Ghana (Jibreel et al. 2013; Mohammed et al. 2013; Alhassan 2020). However, to date, the processing of shea kernels is still done using traditional techniques (Akinsokeji et al. 2017; Agúndez et al. 2019), suggesting that the modern technologies are not accessible to all women (Kabiru & Ayanfunke 2018). Given the coexistence of these two production methods, it is critical to investigate their relationships with productivity or output to determine definitively the potential of each to contribute to overall productivity in Ghana. There is, however, a dearth of knowledge on the comparative efficiencies of the traditional and modern methods of production, including how they contribute to the profitability of processors. Also, under-researched are the problems these processors face and the types of value additions they use to enhance the quality and quantity of butter during the production process. Answers to these questions would not only fill the gaps in the literature but also form the basis for interventions that enhance productivity and, consequently, the livelihoods of shea butter processors.

1.2 Objectives

The objectives of the study include:

1. To examine the relationships between indigenous and modern shea butter processing technologies and production efficiency.

1. To examine the challenges processors face in the production of shea butter.
2. To examine the cost and profit structures of processors who use modern and indigenous technologies in shea butter processing.
3. To investigate value additions in the shea butter production chain.

1.3 Research questions

The following questions are proposed to direct the study to fulfil the aforementioned objectives:

1. What are the relationships between modern and indigenous shea butter processing technologies in Ghana and shea butter output?
2. What potential uses exist for waste from shea butter production?
3. What are the challenges of shea butter processing in Ghana?
4. What are the relationships between modern and indigenous shea butter processing technologies and profitability?
5. In what ways do shea butter processors add value to the production chain?

1.4 Operationalisation of concepts

Efficiency of production: efficiency is examined in this study by considering the absolute quantities and quality of shea butter output relative to inputs, in particular shea kernels.

Modern and indigenous technologies: in the methods section, the nature of these technologies is outlined (figure 5). Processors classified as using modern technologies are those who use drum roasters and electric or mechanical milling machines in three of the key stages of production:

crushing of kernels, roasting of kernels, and milling of kernels into paste. Processors who roast, crush, and mill shea kernels with traditional tools are said to use indigenous technologies.

2 Literature Review

2.1 The shea tree

2.1.1 Shea distribution in sub-Saharan Africa and Ghana

The Shea Tree has been in existence for centuries, with records of its uses dating to ancient Egypt, where Shea trees were used as funeral beds for kings, and its butter used in healing and skin care (Goreja 2004). The tree can be found within the semi-arid areas of the Savannah Woodland Belt (Acema et al. 2021). It is of the 'Sapotaceae Family' with the subspecies *Vitellaria* (Nguekeng et al. 2021). Its subspecies *paradoxa* can be located in Western and Central Africa, whereas Eastern Africa is known for the *nilotica* subspecies (Hatskevich et al. 2011; Nguekeng et al. 2021). Both trees have differences in Shea butter production. That of Western Africa is denser whereas in Eastern Africa *nilotica* Shea butter is more liquid (CBI 2021).

The tree becomes resistant to fire after passing the germination stage (3 to 5 years) (Hatskevich et al. 2011). After this stage, it grows slowly, taking about 15 to 25 years to reach maturity (Hatskevich et al. 2011; Tiamiyu et al. 2014) and can live for up to about two hundred years bearing fruits (Tiamiyu et al. 2014). The butter from the Shea tree may be white to yellow and depends on how refined the butter is (Abdul-Mumeen et al. 2019). Prior to extraction, however, there is a process of treating the Shea fruits. Shea butter processing is seasonal, and the collection of nuts starts from May to August each year (Honfo et al. 2013a), and within this period, the nuts are processed into Shea kernel (Maanikuu & Muotono 2017). The ripe fruits feel soft to touch and may be green or yellowish, composing of the mesocarp and epicarp (which together form the pulp), and the kernel (which bears the oil) and shell which form the nut (Abdul-Mumeen et al. 2019).

It has several uses and purposes and has been explored over the decades. Yet, information on ways to improve marking of Shea and the growing conditions of the Shea tree is often limited (Al-hassan 2015). Regardless, the largest Shea producers are Ghana, Northern part of Uganda, and Nigeria (CBI 2021). Other sub-Saharan African countries like Burkina Faso, Cote D'Ivoire, Benin, Mali, etc. produce Shea butter, but not as much as the aforementioned leading producers (Jibreel et al. 2013; Bup et al. 2014). When put together, the Shea producing countries and areas cover about four million kilometres square of land across sub-Saharan Africa (USAID & Winrock International 2018).

Shea trees are abundant in almost half of Ghana, where the study is being conducted (Abujaja et al. 2014; Jasaw et al. 2015). In 2004, Ghana was reported to have the potential for Shea nut production of 200,000 metric tonnes each year, with the estimated actual quantity collected being 130,000 metric tonnes (Sikpaam et al. 2019). In a report in 2018 however, Ghana was found to be the fourth largest Shea producer, supplying 94,000 metric tonnes per annum and known for the quality nuts produced (USAID & Winrock International 2018). In addition, the estimated capacity for kernel extraction is 226,000 metric tonnes per annum, yet over half of the capacity being met through imports from neighbouring countries who also have limited processing and extraction facilities (USAID & Winrock International 2018).

The industry earns a foreign exchange of 30 Million U.S. Dollars, and this could triple if the tree is fully exploited (Hatskevich et al. 2011). However, recent estimates indicate that the high yield of dried Shea nuts makes the tree one of the most important crops in the sub-region, besides oil palm (Ministry of Economy and Industry & Embassy of Israel 2020). The Shea trees cover over 77,600 kilometres square of land across Volta, Oti, Ashanti, Eastern, Bono, Ahafo, Bono East, Upper East, Upper West, Savannah, North East, and Northern Regions (Hatskevich et al. 2011; Jasaw et al. 2015), majority of which are in Northern Ghana. Yet, in 2007, it was found that about 35 per cent of harvest in Africa are exported as Shea Butter (Okorley et al. 2008). This indicates an under-exploitation of the Shea tree in Ghana and the rest of sub-Saharan Africa (Kodua et al. 2018).

2.1.2 Potentials and uses of shea tree

As aforementioned, the Shea tree has numerous benefits for individuals, households, and countries. These benefits range from health through to income, and then revenue for the country. Socio-culturally, it has been found that the Shea tree is used in making beds, has medicinal benefits of aiding couples in pregnancy and childbirth, and is used in weddings and war rituals (Acema et al. 2021). In addition, the butter extracted from Shea trees has soothing properties and accelerate healing after circumcision (Israel 2014). It also prevents stretch marks, especially for pregnant women (Abdul-Moomin et al. 2016), and acts an insect repellent while protecting users from infections (Israel 2014).

The ivory coloured or off-white Shea butter, which is popularly known as *'nkuto'* in Ghana can also be used in preparing soaps, cosmetics, and could replace cocoa butter in chocolates (Israel 2014; Akinsokeji et al. 2017; Abdul-Mumeen et al. 2019; Nguekeng et al. 2021). The butter also has oleic, linoleic stearic acids, and during crushing and boiling of the nuts, these acids can be absorbed into the skin, and can also be ingested (Asemave & Kaana 2015; Maanikuu & Muotono 2017). In actual fact, the anti-inflammatory and antimicrobial properties of the Shea tree and its butter have made it useful in treating skin infections and numerous diseases (Israel 2014). Such individual benefits have led to its massive use in Europe as an organic personal care product used in treating damaged hair, anti-ageing creams, and prevention against diaper rush among others (CBI 2021).

Besides the associated health benefits, the potential of the tree in livelihood outcomes and poverty reduction have also been examined by practitioners and scholars (Al-hassan 2015). The collection and processing of the Shea nuts are done by women and children, and in doing so, they consume the fruits of the Shea tree (Ademola & Oyesola 2012). In addition, Shea butter contains edible fats and as such, can be used as a source of fat in the foods prepared and consumed (Amegah et al. 2019). Being rich in iron, sugars, protein, ascorbic acid and calcium (Honfo et al. 2013a), the tree could aid in numerous development programmes that deal with sustenance (Gyedu-Akoto et al. 2017). It could improve food security, especially as its fruits can be harvest in the lean seasons when there are food shortages (Naughton et al. 2017).

Women in the rural areas can also sell the processed Shea butter for income (Jibreel et al. 2013; Abujaja et al. 2014; Buvinic et al. 2020). In fact, Shea processing communities often attribute their income source to Shea butter and as such the community or locality benefits from Shea production (Gyedu-Akoto et al. 2017; Naughton et al. 2017). The kernels from the tree, processed into butter and cake, also have economic importance to countries. It generates revenue for countries involved in Shea production, improves foreign exchange, and aid in poverty alleviation programmes (Jamala et al. 2013). In addition, the Shea tree could produce large amounts of sap which can be an important raw material source for the rubber and gum industry (Hatskevich et al. 2011; Oluwalana & Sowunmi 2017). One of the key potentials of Shea production and processing identified in the past decade has been its linkage to achieving the fifth Sustainable Development which seeks to "achieve gender equality and empower all women and girls" (United Nations 2015 p. 18). Shea processing could empower women economically as it improves livelihoods of the millions of women involved in the collection and processing of Shea nuts in the Savannah (Naughton et al. 2017).

The reality in Ghana, however, is that although there are numerous potentials and uses of the Shea tree, the Northern part of Ghana, known for its high production of Shea products remain the poorest in Ghana (GSS 2018). Its abundance during the lean season may potentially reduce vulnerability of women, yet evidence suggests that women in Shea processing make menial profits when compared to others within the Shea value chain (Banye 2014). In 2015, Institute of Statistical Social and Economic Research reported that Shea pickers make less than GH ¢113 per season (from 2.5 bags), which is lower than the per capital income of USD 1,858 (Ghana News Agency 2015). One of the key reasons identified for such low income includes the lack of accessible modern processing techniques for female Shea processors within sub-Saharan Africa and active use of traditional processing techniques (Abdul-Moomin et al. 2016).

Even though there are other stages in the Shea value chain, it is important that countries ensure that the lowest stages (Shea kernel collection and processing) are prioritised as majority of Shea producers fall within that category. Poor rural women could therefore be empowered if attention is processing techniques used, the reasons for such use, and the barriers to improved technology, as these become challenges for the female Shea processors. The ensuing sections therefore explore both processing techniques in detail, and discusses their efficiency, and challenges and effects on women's empowerment.

2.2 Shea processing technologies

There are two main processes for extracting Shea butter popular within Africa and in Ghana, and these are the traditional and modernised methods of extraction (Abdul-Moomin et al. 2016). Prior to extracting from the fruit, it goes through some processes, which are predominantly done by women (Jasaw et al. 2015; Sikpaam et al. 2019). First is de-pulping where the soft pulp made of epicarp and mesocarp are removed from the ripe fruit, either through manual peeling or fermentation (Abdul-Mumeen et al. 2019). Fruits stored prior to de-pulping should not exceed three days as this could affect the quality and quantity of Shea butter (Aculey et al. 2012; Ojo & Adebayo 2013; Abdul-Mumeen et al. 2019). The next stage is boiling the Shea nuts where the obtained kernel and shell are separated through immersion in boiling water for up to two hours (Honfo et al. 2013a), to deactivate the enzymatic and biological activities within the nut (Abdul-Mumeen et al. 2019). When the kernel is boiled, it increases the fat output as boiling softens the Shea nuts and disrupts its cells leading to better oil release (Honfo et al. 2013a; Nguekeng et al. 2021). It also cleanses remaining fruit pulp, which could increase microbial growth, from the surface (Abdul-Mumeen et al. 2019).

In the next phase, the Shea nuts are dried for up to 15 days (Honfo et al. 2013a), depending on the drying method. Using sunlight takes longer, and is more widespread at reducing the content of moisture in the nuts (Tiamiyu et al. 2014; Abdul-Mumeen et al. 2019), whereas using an oven could take up to 3 days (Nguekeng et al. 2021). These initial stages are key to the quality of kernel produced and if not done well, it would increase peroxide value, free fatty acid, and fungal levels and thus hinder the entry of the final products into Europe and United States of America due to their carcinogenic properties (Asemave & Kaana 2015).

The next pre-extraction step is de-shelling. During the drying process, nuts are detached from the wall of the shell. The nuts are then de-shelled using hammers, stones, and pestles (Nguekeng et al. 2021). This is followed by winnowing where baskets are filled with the kernel and shells and held at arm’s length to allow a pour out and use the wind to blow away shell pieces (Abdul-Mumeen et al. 2019). Clean unbroken Shea kernels are then sorted out and can be stored for months without affecting quality of the Shea butter extracted in later stages.

2.3 Traditional processing techniques and its efficiency

Within the SSA sub-region, and more specifically, in Ghana, the production of Shea butter is done by women who predominantly use traditional processing methods, also called the wet process of extraction (Nde et al. 2016; Abdul-Mumeen et al. 2019). The higher use of such methods has mainly been attributed to the lack of knowledge and access to modern processing techniques within the sub-region (Nde et al. 2016). The traditional process begins with reducing the size of the kernels by pounding them using a pestle in a mortar, and then dehydrating the reduced kernels by roasting them to aid in extracting the oil (Jasaw et al. 2015). After roasting, the grits obtained are grounded to paste traditionally using stones. Roasting and reducing kernel size has been deemed important, since it increases the surface area needed for effective hydrolysis during the kneading process (Abdul-Mumeen et al. 2019). Other scholars also report of high fat quality being linked to blanching/roasting of the Shea nuts (Tame et al. 2015; Honfo et al. 2017).

The next stage of the traditional process is the kneading of the nuts, where oil cells are broken up to ease the extraction of oil. Each kneading session may take an average of 30 minutes to complete and involves adding about 3 litres of cold water to a reasonable amount of Shea paste, and then stirring with the hand until butter begins to rise (Jibreel et al. 2013; Abdul-Mumeen et al. 2019). The success of the kneading process is dependent on one's experience with extracting Shea butter, and once it is done, the oily layer on the surface is harvested, washed with water, undergoes boiling to evaporate the water, and then the fat is decanted and cooled (Abdul-Mumeen et al. 2019). Shea butter then solidifies and can be sold for use.

2.4 Modern processing techniques

The semi-mechanised and mechanised technologies used in processing constitute the modern shea processing techniques. Within the modern methods, dry kernels are put into the heating chamber or boiler to temperatures of about 20ºC, after which they are directed into the crushing unit, reduced in size, pressed, and filtered to acquire the oil (Abdul-Mumeen et al. 2019). After this, the remaining cake is put in another expeller and pressed for the second time to produce more butter, then the Shea butter is cooled and solidified (Abdul-Mumeen et al. 2013). This process attempts to increase efficiency in the yield of Shea butter, while reducing the time and labour spent in the traditional processing method. One of the earliest investigations into mechanised processing technologies was reported in 1988 (Marchand 1988). His work showed that a Shea butter press, when equipped with a jack exerting a force of 30 tonnes, would crush over 3 kilograms of Shea kernels within 20 minutes. This press could also extract about 85 per cent of the fat in the kernel without having to go through the numerous heating stages and use of fuelwood.

There have been reports of the introduction and use of hydraulics, mechanical presses, and rotary roasting equipment, both locally and foreign designed (Abdul-Mumeen et al. 2019; Tulashie et al. 2020). A report from the Dagomba women in Ghana, who were the first to make use of mechanised systems of Shea butter extraction, shows that the modern methods have led to shorter processing times, and have enhanced the use of water (Horizon International Solutions Site 2011).

This processing is usually carried out with a boiler, filter press and mechanised press systems (Abdul-Mumeen et al. 2019).

Several other innovative technologies, which often target different phases like kneading machines (for kneading), hydraulic hand presses, solar dryers, mixers, and heaters (Marchand 1988; Abdul-Mumeen et al. 2019). Grinders are used in place of pestles and mortars, and huge amounts of water used with the traditional methods are reduced (Ademola & Oyesola 2012). This is especially helpful for such arid areas, where acquiring water for such use is often difficult. The use of roasters also reduces the time and energy use, and reduces the exposure to fire. Kneaders can also use modern methods to emulsify the milled kernel into one that can readily be heated, instead of using their hands (Jibreel et al. 2013). It is important to note that most of these technologies are often introduced in the form of experiments and never scaled up, and they are expensive for the ordinary processor to access. They are also sometimes introduced by non-governmental organisations in the form of programmes and are discontinued when the programmes expire. For these reasons, only simple, inexpensive technologies that eliminate some traditional technologies are prevalent in Ghana and examined in this study.

2.5 Challenges with shea processing

Based on one's processing technique used, several challenges may be associated within the various stages in Shea processing. For instance, as also noted in the efficiency level of the traditional methods, some challenges associated include time consumption, labour intensiveness, and higher demand for water and fuelwood among others. Shea processors may face the risk of being bitten by snakes and being stung by scorpions (Abdul-Moomin et al. 2016). This is because oftentimes, protective clothing like gloves, rain coats, and boots are unavailable to the women, leading to high incidences of bites and stings during Shea nut collection (Abdul-Moomin et al. 2016; Sualihu 2019). Time consumption has also been one of the most highlighted challenges associated with traditional Shea processing techniques (Ademola et al. 2012). Besides spending hours to pick up Shea nuts, a lot of time is used to manually process nuts into butter. In removing the fruits' pulp, it becomes a slow, yet arduous task, and requires a lot of labour (Adam & Abdulai 2014). Mixing is also done by hand, and as such can be time consuming. In addition, inadequate water supply, unfavourable weather conditions, and higher consumption of fuelwood have been found to be challenges with the traditional processing techniques (Ademola et al. 2012; Adam & Abdulai 2014; Abdul-Moomin et al. 2016; Ajala et al. 2016).

Modern processes, however, reduce such time and have been found to aid in reducing the challenges associated with traditional processing methods. Yet, processors who make use of such methods may face problems with inadequate equipment, electricity supply and finance associated with the modern processors (Adam & Abdulai 2014). Mechanised systems are costly (Jibreel et al. 2013; Tulashie et al. 2020), and as such, cannot be used all the time. The press for Shea butter is not affordable, and remains unavailable for majority of the female Shea processors in rural areas (Abdul-Mumeen et al. 2019). Another observed shortcoming of the press machine is that, although better than use of traditional methods, the press may leave up to 19 per cent of fat remaining in the cake (Abdul-Mumeen et al. 2013, 2019).

2.6 Uses and environmental impacts of waste from shea butter processing

The manufacturing of shea butter, much like the manufacturing of any other product, results in the generation of a sizeable amount of waste. The name given to this type of waste or residue is shea butter cake. According to Abdul-Mumeen et al. (2013), it is estimated that Ghana's shea industry produces approximately 500,000 tonnes of shea butter cake each year, with 450–600 kg of shea nut cake being produced for every metric tonne of shea nuts that are processed. This indicates that waste is produced at a rate of between 45 and 60 percent for every unit of nuts that is processed, and that the primary components of this waste are water and solid matter. This high rate of waste to butter ratio varies depending on the types of technologies employed; without a doubt, processors employing the least efficient production technologies would produce more waste than those who employ the most efficient production technologies. The reason for this is that they would not be able to grind the nuts into the smoothest paste possible, which would, in turn, reduce the amount of butter they could ultimately extract.

Most processors either put this waste to some form of use or dispose of it, and usually, they dispose of it indiscriminately which has negative impacts on the environment. Shea butter waste, which is constantly piled up at processing sites, emits an offensive odour that has an impact on the health of residents who live nearby. In addition, during the rainy season, dried shea cake that has been carried by rainwater contributes to clog gutters, which in turn contributes to flooding

(Sarkodie et al. 2016). It is also documented that the “disposed slur inhibits plant growth and contributes to changing the soil structure” (Jibreel et al. 2013). The proximate traits of the shea butter cake observed in some studies are illustrated in figure 1 below.

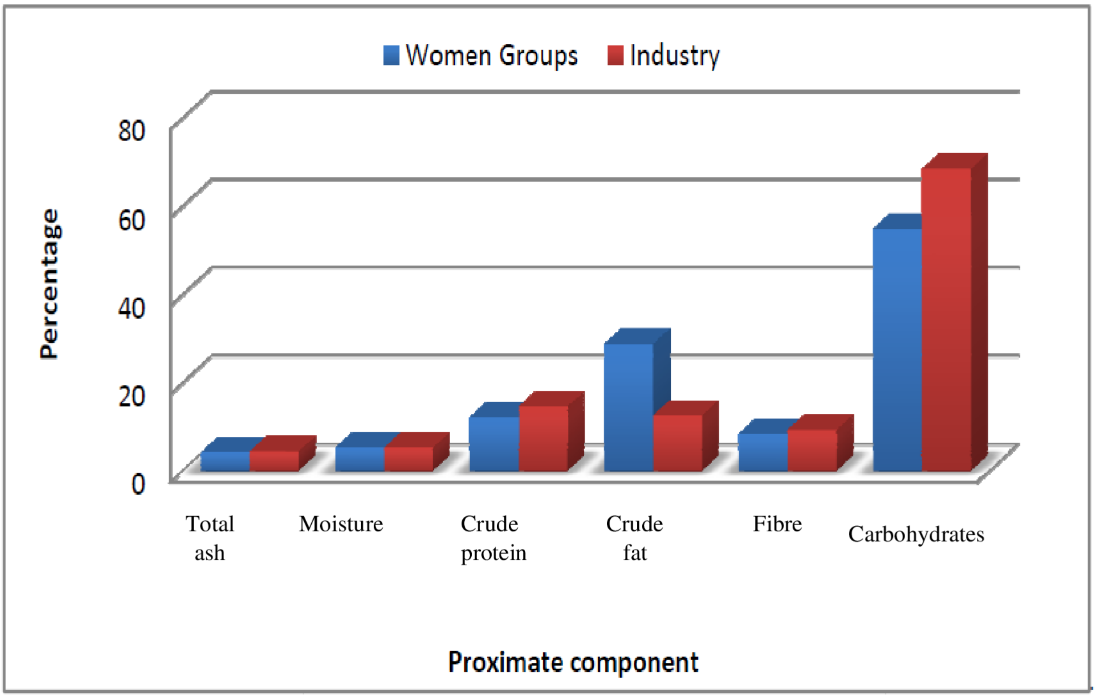

Figure 1: Proximate traits of shea butter cake (waste) (source: Abdul-Mumeen 2013, 963).

According to the findings of the research carried out by Abdul-Mumeen et al. (2013), which compared shea butter cake obtained from a processing plant with that of those obtained from local processors using various kinds of technologies, it is evident that the proximate properties of shea butter cake vary from one group to the other. In addition, it demonstrates that the majority of shea butter cake is made up of carbohydrates, followed by crude fat and crude proteins. Because of these properties, the waste that is produced during the manufacturing of shea butter may be put to a variety of uses. Following a review of the literature in this study, a list of these uses will be compiled.

3 Methodology

3.1 Introduction

This section provides an overview of the methodology that was used to design and carry out the study. Thus, it includes the research strategy, design, sampling, analysis techniques, difficulties the researcher faced on the field, and ethical considerations.

3.2 Research design

The study relied on the quantitative approach to inquiry, with a survey design being used. The quantitative approach to research aims to explain changes in variables using numerical measurements and analysis (Firestone 1987). This method allows the researcher to study a subset of a population to draw conclusions about the entire population based on what they find out about the subset (Creswell and Creswell 2017). Specifically, the study was a cross-sectional survey that employed both closed- and open-ended questionnaires to elicit responses from shea processors in three different locations in the northern region of Ghana on a variety of variables.

3.3 Study sites, sampling, and the researcher's experience with shea processing

The northern region was selected for the study because the researcher had access to contacts familiar with the culture and terrain of the region. In addition to this region, three other regions: the northeast, upper west, and upper east regions—are also home to bountiful shea trees, from which shea fruits are picked and processed for different uses and markets. The specific communities from which the survey instrument was administered are Savelugu, Kunbungu, and four other villages under Kunbungu, where, for now, shea butter processing is entirely carried out using traditional technologies. Collectively, these villages would be referred to in this study as "traditional community." For Savelugu and Kunbungu, some stages of production-particularly the crushing of kernels into grits, the roasting of gritted kernels, and milling-are done using small-scale machines or technologies.

The researcher first visited these communities and shea butter processing centres to have a firsthand understanding of the production processes. In Savelugu and Kunbungu, there are organised groups of shea processors, mostly led by nongovernmental organisations (NGOs). This facilitated the survey administration as it enabled the researcher to explain the study's objectives and processes to many people at a time before administering the survey instrument. The researcher had aimed at administering the survey instrument to half of each of the groups identified in Savelugu and Kunbungu; however, this was not achieved because not all members are engaged in shea butter processing all the time. Realizing this, the researcher changed the respondent selection strategy to include any processor who was available at the time and willing to participate. Through this process, 58 questionnaires were administered to processors at organised production centres. 25 other processors who are not under any organised centres were surveyed in these two towns through a snowball sampling approach with the help of the processors under the organised centres. For the traditional community, the researcher also randomly surveyed 19 respondents. In all, 103 respondents were surveyed. Figure 2 is a map of the northern region of Ghana, with the arrows pointing at the places where the survey was conducted.

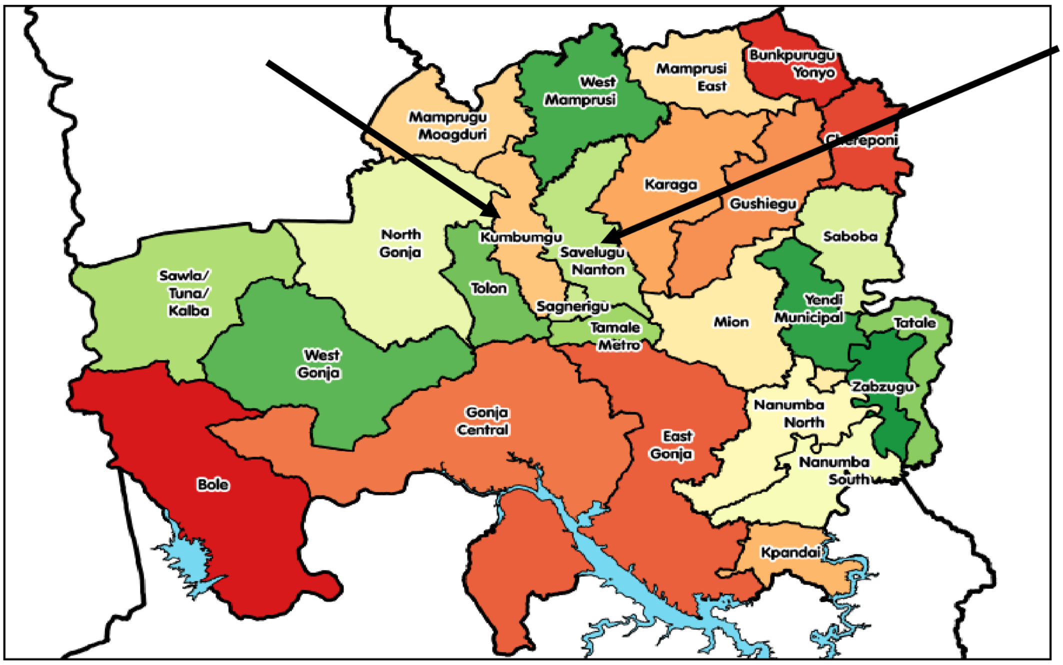

Figure 2: A map of the Northern region of Ghana with the arrows showing where the survey was conducted.

3.4 Research experience and shea butter production processes

The visits to the processing centres were important as they allowed the researcher to observe and gain first-hand knowledge of the production processes. It should be noted that there are currently no modern technologies to simplify or replace the traditional technologies or processes in some of the stages of shea butter production. An example of these stages is churning or whisking kernel paste, which the local people call "beating," a label derived from the fact that they whip the milled shea paste with their bare hands. Figure 3 below shows shea tree fruits as well as shea kernels, while figure 4 shows a milling machine and the churning of kernel paste.

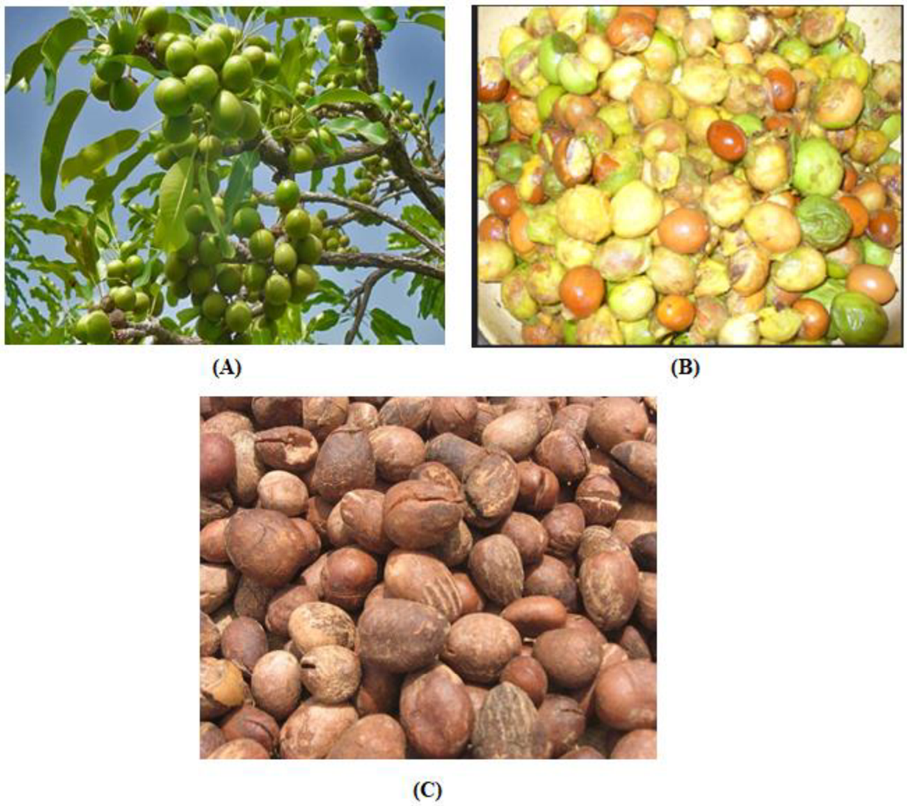

Figure 3: Shea fruits on shea tree (A), depulped shea fruits (B), and shea kernels after dehusking (C) (Source: Google images).

Figure 4: Electric milling (left) machine and processors kneading milled kernels with hands (right) (Source: Field observations).

For the crushing, milling, and roasting of shea kernels, the processors were observed to use some technologies. The organised processing centres have these simple technologies, which, according to the processors, were provided by some NGOs. The processors only paid for the cost of using the centre's services, such as milling charges. There were other processors who also acquired and used the same technologies and therefore are not under the control of any organised centre. Collectively and for simplicity, this group of processors is treated as using modern technologies. It should be noted that within the shea-producing regions, there are about three fully mechanised shea butter processing plants, but all attempts to interview them proved futile. This was not unexpected, as some informants had already pointed out this fact.

Most of the processors appeared happy to work under an organised centre rather than privately, for some reasons. For instance, the managers of the centres have arrangements with shea butter buyers who come regularly to the centres and buy processed butter. This eliminated the cost of transporting processed shea butter for sale, storage costs, and other marketing impediments. Producing quality shea butter is implicitly a condition for maintaining customers and getting good prices; as a result, the centres ensure that processors follow procedures that result in quality butter output. Figure 4 shows three of the last cycles of processing shea butter, whereas Figure 5 summarises the entire processes involved in shea butter processing, which also distinguishes between the two technologies of production-modern and indigenous.

(A) (B)

(C)

Figure 5: Whipped butter (A), boiling/heating of shea butter (B), and cooling of butter (C) (source: Field observation).

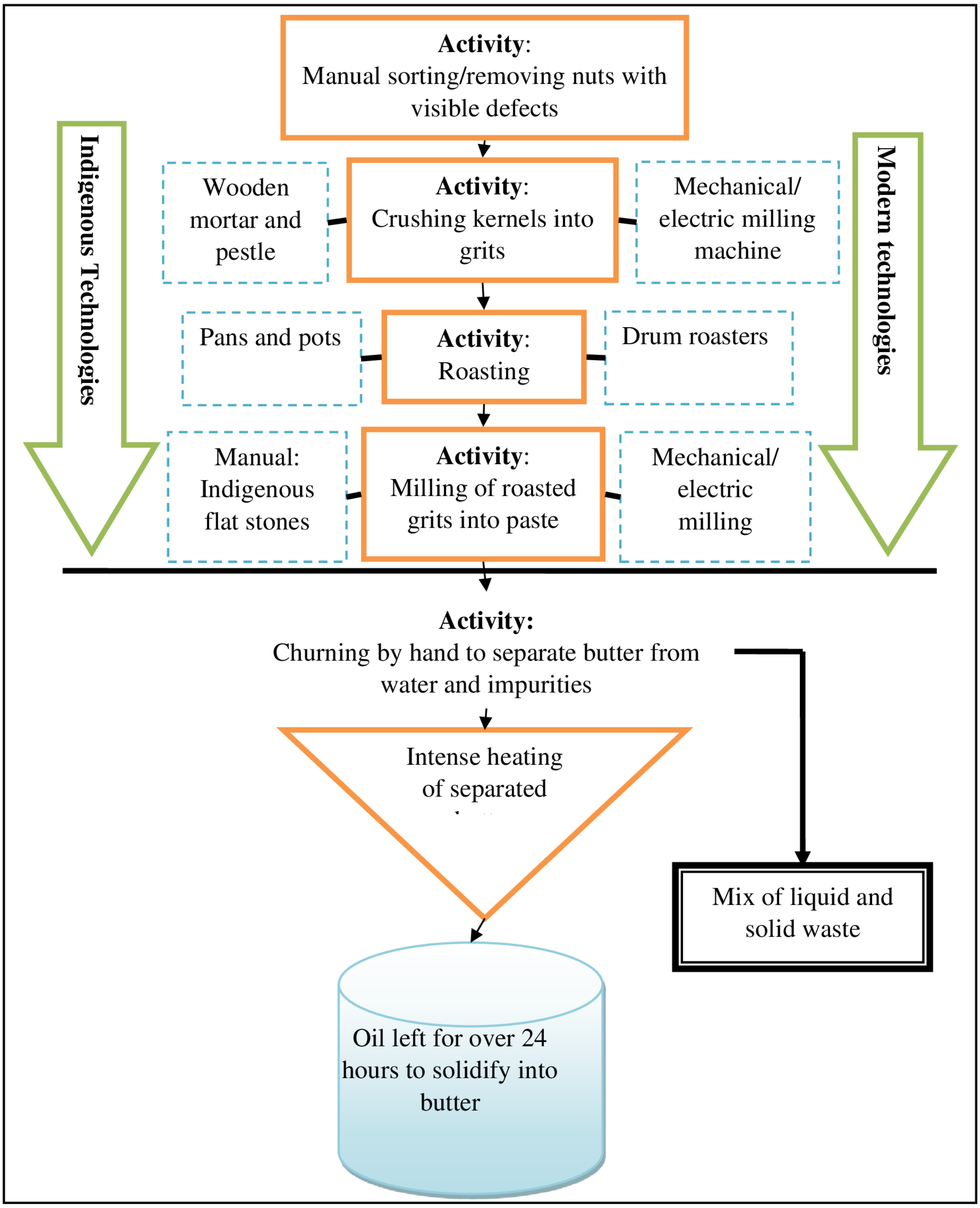

Figure 6: A summary of the field observation of the production processes of shea butter.

3.5 Instrumentation

The design of the survey instrument took several steps. After the initial design, the researcher, to enhance its face validity as advised by Bryman (2012), approached two volunteers from Ghana who has experience in research in the shea industry to assess the questionnaire to ensure that it was in line with the study's objectives and the variables to be captured. After assessing the questionnaire, they gave useful comments which helped improved it. The variables of the study were also informed by the rich literature in shea processing, which contributed to also improve the validity of the study's key constructs as advised by Bryman (2012). The questionnaire was also tested on a few volunteers who reflected the intended study population to determine its ease of use on the target population. An online survey tool used to design and administer the questionnaires, and data collection was undertaking with the aid of a tablet/smart phone.

3.6 Variables of the study

Data was collected from respondents on several variables pertinent to the study's objectives. The closed-ended questions captured respondent's demographic variables, the fixed and variable inputs associated with shea butter processing, production challenges and perceptions of shea butter quality. The open-ended questions elicited responses associated production challenges and value addition measures. The study and the questions were structured such that all data collected were on activities of processors within a week. This allowed for the direct linking of all costs to inputs and outputs. Appendix 1 is the study's questionnaire showing all the questions.

3.7 Data analysis

The data were subjected to a variety of analyses, which are all detailed in the following sections. Analysis was done using both IBM SPSS Statistics (Version 28) and Microsoft Excel.

3.7.1 Efficiency of production

Butter Extraction rate:

$$\text{Extraction rate} = \left(\frac{quantity\ of\ shea\ butter\ (kg)}{quantity\ of\ shae\ kernel\ (kg)}\right) * 100 \qquad (1)$$

Correlation and regression analysis: A Spearman correlation analysis was conducted to determine the relationship between technology use and extraction rate. The Spearman was considered appropriate because technology use was treated as a categorical variable. After the correlation analysis, two sets of regression analyses were conducted to determine the amount of change in extraction rate that could be attributed to technology use. The first was a bi-variate regression analysis with technology as an independent variable and extraction rate as a dependent variable. A multiple linear regression analysis was done to find out if the relationships found here are by chance or to separate the effects of other variables that also affect the extraction rate. A list of all the variables is in table 1. The model was specified as:

$$y = b_0 + b_1x_1 + b_2x_2 + \dots + b_nx_n + \varepsilon i \qquad (2)$$

Where:

y = dependent variable (extraction rate),

$b_1 \dots b_n$ and b_0 = coefficients to be determined,

$x_1 \dots x_n$ = independent variables and

εi = statistical noise (residual error).

Table 1: Variables in used in the regression analysis.

Variable	**Description**
Extraction rate	Continuous variable
Use of modern technology	Yes = 1; No = 0
Age of processor	Continuous variable
Educational level of processor	Below secondary school = 1; otherwise = 0
Experience in processing (in years)	Continuous variable
Quantity of kernel	Continuous variable
Units of labour (unpaid)	Continuous variable
Units of labour (paid)	Continuous variable

Butter quality: The taste, odour, texture, and smell of butter were the qualities used as proxies for the quality of butter. The researcher had a sample of butter, which several people agreed had the best taste, odour, texture, and smell. To determine the processors' perceptions of the quality of their butter, this was then shown to every respondent, who was then asked to rate, on a scale of 1 to 5, how theirs compared to theirs. The results from this were then analysed descriptively.

3.7.2 Assessment of cost and profitability

Two types of costs were assessed for each processor: total cost (TC), total variable cost (TVC), and total fixed cost (TFC). Fixed cost includes cost on items that are constant through the production processes, such as drum roaster, pans, pots and storage containers. After determining the costs of fixed items, processors were asked about the life span of such items. For example, most of them stated that they could use their drum roasters for three years. The average cost for these drum roasters was GH₵500. These costs were then spread across the number of weeks in three years (156 weeks), and from this, the contribution of fixed costs on drum roasters for a week was determined for each processor. The same was done for all fixed inputs in this study. Variables cost is normally incurred on items that are inconstant in production cycles and stages, and they included among others, cost of raw materials (shea kernels), transportation cost, market tolls, labour, energy. There were specific survey questions that elicited data from which all costs were estimated.

Equations for costs and revenues:

$$\text{TC} = \textit{Total variable cost (TVC) (GH₵)} + \textit{Total fixed cost (TFC) (GH₵)} \tag{3}$$

$$\text{Total Revenue (TR)} = \textit{Quantity of butter} \times \textit{price of butter (GH₵)} \tag{4}$$

Where: GH₵ = Ghana Cedis; TC = Total Cost

Net Income (NI): This is Gross Margin (GM) minus Total Fixed Cost (TFC), and a positive NI suggests that a firm is profitable (Kodua et al. 2018). It is expressed as:

$$NI = GM - TFC \tag{5}$$

Where: NI = Net Income,

GM = Gross Margin; TFC = Total Fixed Cost

Gross margin: this is a firm's total revenue minus its variable cost and helps to compare the efficiency of firms (Firth 2002). It is expressed as:

$$GM = TR - TVC \qquad (6)$$

Where: GM = gross margin

TR = Total Revenue; TVC = Total variable Cost

Return on Investment (ROI): According to Zamfir, Manea, and Ionescu (2016), return on investment (RIO) reveals how much money was made or lost from a given action, and it allows for the evaluation of an investment's effectiveness or for comparing results to the methods employed to achieve them. It is expressed mathematically as:

$$ROI = \frac{NI}{TC} \times 100 \qquad (7)$$

Where: ROI = return on investment; NI = Net Income; TC = Total Cost

Determinants of profitability: A simple linear regression model was used to determine the factors that have impact on profitability. Gross Margin (GM) was entered as the independent variable. The GM has been used as an independent variable in some studies (Kodua et al. 2018). The lists of the variables are in table 2. The model was specified as:

$$y = b_0 + b_1x_1 + b_2x_2 + \ldots + b_nx_n + \varepsilon i \qquad (8)$$

where:

y = dependent variable (Gross margin - GM),

$b_1 \ldots b_n$ and b_0 = coefficients to be determined,

$x_1 \ldots x_n$ = independent variables; and

εi = statistical noise (residual error).

Table 2: Description of variables used in the profitability analysis regression model.

Variable	Description
Gross margin	Continuous variable
Use of modern technology	Yes = 1; No = 0
Level of education	Below secondary school = 1; otherwise = 0
Number of paid employees	Continuous variable
Number of unpaid employees	Continuous variable
Membership of cooperative	Yes = 1; No = 0
Age	Continuous variable
Years engaged in shea processing	Continuous variable
Marital status	Married = 1; otherwise = 0
Records keeping	Yes = 1; No = 0
Quantity of kernel processed	Continuous variable

3.7.3 Challenges of production

There were closed-ended questions that elicited data regarding production challenges. There was also an open-ended question that allowed processors to state the challenges that they face. This allowed for the triangulation, "the mixing of data or methods so that diverse viewpoints or standpoints cast light upon a topic" (Olsen, Haralambos, and M. Holborn 2004, 3). The results from these two data types were analysed descriptively.

3.7.4 Value addition in shea butter production

Value is added to a product by "changing its current place, time, and form characteristics to characteristics more preferred in the marketplace" (Coltrain, Barton, and Boland 2000, 5). This has hardly been explored among local shea butter processors; as a result, this question was largely an exploratory one. The data pertaining to value addition was therefore analysed qualitatively.

3.8 Ethical considerations

Due to the inclusion of informed consent procedures, any potential ethical concerns were mitigated. Participants were provided with an explanation of what the research entailed prior to making an informed decision regarding participation. Respondents were often told that their participation was voluntary, and that they were free to terminate their participation if they feel the need to do so. Respondents were also often assured that their privacy would be protected and that their participation was for scientific purposes only. The researcher also sought and received the necessary ethical clearance from the appropriate departments at her university before undertaking the field work aimed at collecting data for the study.

4 Results

This chapter presents the findings of the study. It begins with descriptive statistics regarding the demographic characteristics of the study's sample. After this, the findings relating to the research questions posed in Chapter 1 are presented chronologically.

4.1 Processors' socio-demographic characteristics

Table 3 4 and 4 summarises the socio-demographic information concerning the processors surveyed in this study. From the table, out of 103 processors surveyed, only one was male. It was quite surprising to find a man engaged in shea butter processing, as women typically perform this task. In contrast to the women, however, who were observed to participate in all stages of processing, the man was merely an entrepreneur who employed several women, and his role was limited to supervision, the acquisition of inputs, and sales-related issues. Nearly 79% of the processors reported being married, and except for women who operated from organised centres, the rest of the married women conducted their businesses from their homes.

Only 23% of the processors reported being either married or widowed, indicating that shea butter processing is primarily a profession for those with low educational attainment (93% of processors had either no formal education or less than secondary education). In addition, more than half of the surveyed processors (55%) worked in organised centres, which, as stated previously, are established by non-governmental organisations and managed in collaboration with women. Most processors (83.55%) also use drum roasters and electric or mechanical mills, which have replaced the indigenous technologies that have existed for centuries (18.55% of processors still employ indigenous technologies throughout the production process).

Table 3: Descriptive statistics of demographic variables of the study.

Variable		Frequency	Percent
Gender (Female)		102	99.03
Marital status	Married	81	78.6
	Single/widowed	23	21.4
Education	Less than high school	93	90.0
	Greater than high school	10	9.0
Having another occupation besides shea processing	Yes	28	27.18
	No	75	72.82
Membership of a cooperative	Yes	57	55.34
	No	46	44.66
Use of modern Technology in processing	Yes	84	81.55
	No	19	18.45
Records keeping	Yes	28	27.18
	No	75	72.82

In table 4 it can also be seen that butter processing is predominantly done by older women, as revealed by the mean age of the processors (M = 46.35, ±SD = 10.77). Unpaid labour is also common in shea processing (M = 8, ±SD = 1.79). This usually takes the form of older children or relatives who live with processors. The labour provided in these cases is seen as extensions of the household chores of the individuals concerned (children, nieces, etc.), and as a result, they do not expect anything in return for their services; they also see their services as contributions to the maintenance of the household. Several of the processors also reported paying for labour (M = 2.08, ±SD = 2.16), and most of them reported paying daily wages of about GH 20 per person. Also important in the table 4 is the amount of kernel processed in a week (M = 156 kg, ±SD = 119 kg). The larger ±SD is due to the inclusion of processors from the traditional community (processors who used indigenous technologies through the production processes) who generally processed smaller quantities of kernels but were combined to determine the mean. From start to finish, it took about three days for processors with kernels weighing more than 120 kg to produce butter.

Table 4: Descriptive statistics of demographic and other variables.

Variable	**Minimum**	**Maximum**	**Mean (M)**	**± SD**
Age	20.00	70.00	46.3529	10.77
Household size	3.00	25.00	9.3431	3.73
Experience (years)	1.00	45.00	11.2621	9.21
Distance (km)	3.22	32.18	12.8329	7.46
Labour (not paid)	1.00	8.00	2.7476	1.79
Labour (paid)	0	10	2.08	2.16
Kernel processed (week)	24.00	850.00	156.3010	119.44
Butter extracted (week)	7.00	349.00	62.8010	49.035
Extraction rate	28.00	41.80	39.2224	2.66

M = Mean and *SD = standard deviation*

4.2 Relationships between modern and indigenous shea butter processing technologies and shea butter output

The answer to this question is based on descriptive and inferential statistics. The first comparison is between the extraction rates of modern and traditional technologies. While in Table 4 the mean extraction rate for the entire sample was 39.22 (±*SD* = 2.66), separate analysis revealed that the mean extraction rate for processors employing modern technologies was higher than that for processors employing indigenous technologies. The illustration in figure 6 below demonstrates this. On average, modern technologies produce 5.35% more butter than indigenous technologies.

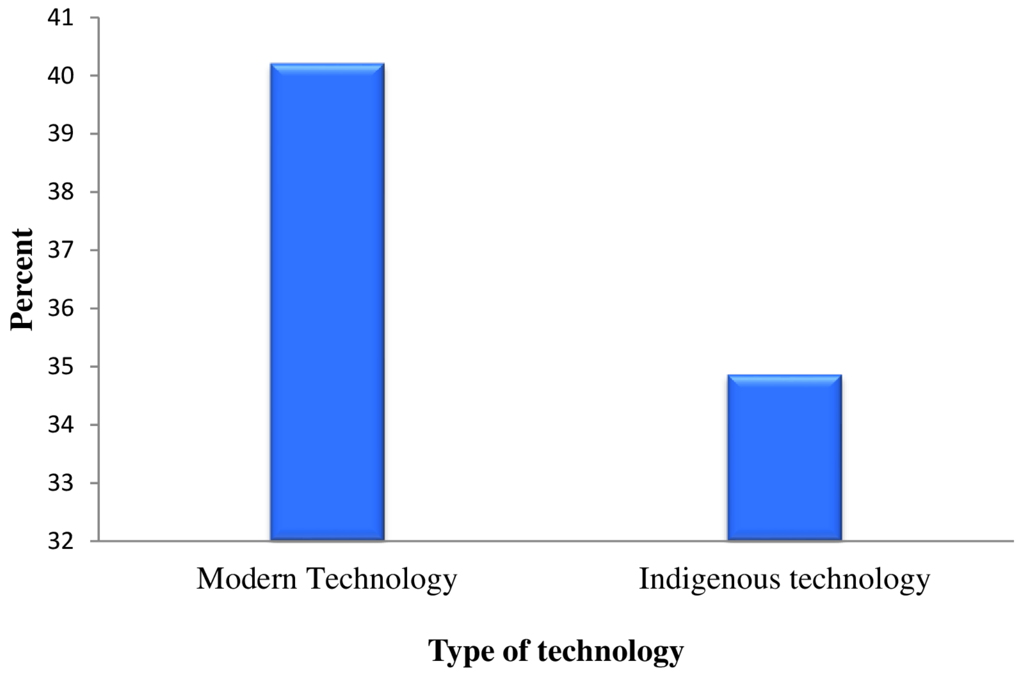

Figure 7: A bar chart showing shea butter extraction rate for two different production processes (source: Field data).

This observation in figure 6 was further analysed through correlation and regression analysis. This was to determine the extent to which changes in technology affect changes in extraction rate. The results of the correlation analysis are shown in table 5. This result shows that there is a strong positive relationship between the proxies of modern technologies in this study and the extraction rate, and the correlation is very strong (r = .66).

Table 5: Correlation between technology use and butter extraction rate.

Indicator	**Kernel (kg)**	**Butter (kg)**	**Extraction rate (%)**
Tech use (yes=1)	$.669^{**}$	$.669^{**}$	$.661^{**}$

*Level of significance: ** p < 0.01, * p < 0.05, all two-tailed*

Due to the small sample size (103), 1000 bootstraps were utilised in the regression analysis. Bootstrapping is a re-sampling technique where the original sample (103 in this study) is re-sampled extensively to arrive at more reliable estimates, and it is recommended when the sample size is small (Mooney et al. 1993, iv). First, a bivariate regression was conducted with extraction rate as the dependent variable and technology as the independent variable. The results of the bivariate analysis in model 1 of table 6 indicate that the extraction rate associated with the use of technology is 5.357 units higher than the extraction rate associated with the use of indigenous technologies, and this difference is statistically significant ($p = .001$).

Table 6: Regression analysis of the predictors of shea butter extraction rate (dependent variable = extraction rate).

Model 1	B	Std. Error	Sig.
(Constant)	34.853	.750	.001
Use of Technology (yes = 1)	5.357	.753	.001
Model 2	B	Std. Error	Sig.
(Constant)	35.961	.937	<.001
Use of Technology (yes = 1)	4.987	.769	<.001
Age	-.037	.025	.138
Education (upper sec and below = 1)	.545	.529	.239
Years of experience	.011	.021	.608
Labour (unpaid)	-.033	.074	.653
Quantity of kernel (kg)	.002	.002	.276
Labour (paid)	.056	.078	.443

B standardised regression coefficient; sig. = level of significance

Recognizing that additional factors influence extraction rate, it was deemed prudent to run a second model that incorporated these additional factors. This allows the isolation of the influence of other independent variables on the dependent variable to obtain the most accurate estimates (Hünermund and Louw 2020). In Model 2, the relationship between the use of technology and the extraction rate remained strong and positive after controlling for the other variables; however, the size of the effect for technology use decreased slightly from 5,357 to 4,987. It is also evident that none of the control variables have a significant relationship with the extraction rate, not even the number of years of shea butter processing experience or the number of kernels used in production. The negative relationship between unpaid labour and the extraction rate is also important to note, although it is not statistically significant ($p = .65$).

4.3 Processors' perceptions of shea butter quality

It was also anticipated that the use of modern technologies may be associated with the quality of butter, but assessing this was one of the difficult tasks, as quality appears to be subjective. However, the method employed to assess quality as outlined in the methodology section was practical and proved effective, allowing for an objective assessment of butter quality. Of all the proxies of butter quality used in this study–odour, texture, taste, and colour–the mean responses in figure 7 shows that processors who used modern technologies rated the quality of their butter higher than those who used indigenous technologies throughout the production processes.

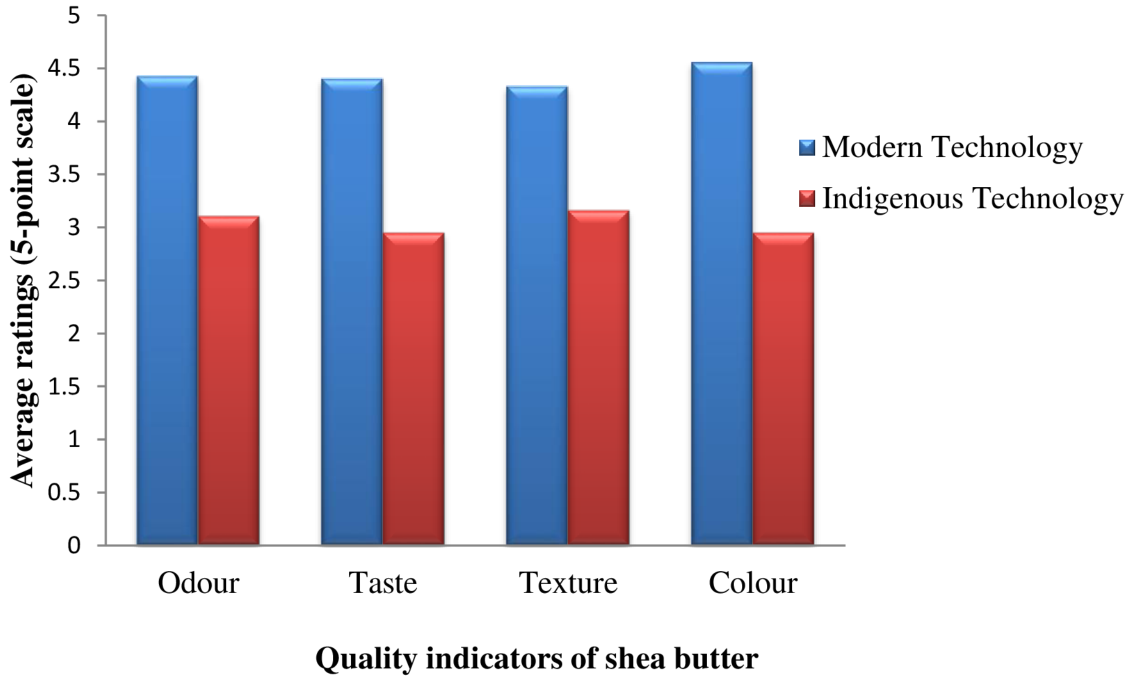

Figure 8: Mean responses for perceptions of shea butter quality (source: field data).

4.4 Uses of waste from shea butter production—a survey of the literature

The literature was also reviewed to compile the various studies on the applications of shea waste. This was to allow the researcher to formulate actionable recommendations on shea waste in Ghana. The reason for this is that there are very few studies on the shea industry in general, and in Ghana, there is almost no research on the uses of shea waste. Another reason was the observation that although studies on the uses of shea waste exist in other jurisdictions, the results of these studies are rarely applied outside of academic contexts. By synthesising the literature and incorporating it into the thesis, it is hoped that it will contribute to popularising the potential uses of shea waste and inspire additional research on the topic. Four uses of shea waste were discovered, which are described in the following sections.

4.5 Shea waste as source of energy

The dried butter cake is sometimes used as biomass in the area; however, this practise is not as widespread as to function as a significant alternative source of fuel for domestic use. According to Houemenou et al. (2021), shea shells and cakes account for 0.28 and 0.43 tonnes of processed dry shea nuts per tonne, respectively. They therefore have a high energy potential, with the shells containing 18.7 MJ/kg of calorific value and the shea cake containing 22.42 MJ/kg of calorific value (Houemenou et al. 2021). In general, the calorific value of shea waste varies between studies due to disparities in analytical procedures and conditions (Houemenou et al. 2021). For instance, a value of 19.55 MJ/kg is reported in Adazabra et al. (2016). Other energy-related properties of shea kernels and cake reported by Houemenou et al. (2021) are in table 7. below. To better comprehend the LCV of shea shells in table 7, it is necessary to compare it to the LCVs of other studied shells. Comparatively, the LCV for coconut shells is 28.059 MJ/kg and that for palmyra palm nut shells is 26.111 MJ/kg (Kongnine et al. 2021).

Table 7: Physicochemical characteristics of shea shell and cake (Source: Houemenou et al. 2021).

Biofuel	Moisture (%)	Volatile Matter (%)	Ash (%)	Fixed Carbon (%)	LVC (kJ/kg)	Carbon Content (%)
Shell	18.0 ± 0.2	77.2 ± 0.4	1.1 ± 0.1	21.6 ± 0.5	19 962	57
Cake wet	33.1 ± 0.4	63.7 ± 0.1	6.6 ± 0.9	29.6 ± 0.9	30 158	85

As a result of the foregoing characteristics, a study of its potential for industrial production, particularly of briquettes, has been undertaken. This is to capitalise on its potential to serve as a significant source of biomass for both domestic and industrial uses. One of such studies is Abubakar et al. (2021) in Nigeria, which indeed “is one of the first attempts to produce a biomass briquette from Shea kernel cake as a potential alternative clean solid fuel for energy supply” (Abubabkar et al. 2021, 11). They were able to create cylindrical butter cake briquettes by mixing the biomass with corn starch and then using a manual briquetting machine to apply pressure to the resulting mixture. According to the findings of their study, the briquettes contain the following types and amounts of gas: carbon (40%), oxygen (41%), hydrogen (8.3%), and sulphur (0.12%), all of which were "within the standard values for briquettes except for nitrogen, whose value was greater than 1%" (Abubakar et al. 2021, 8).

Still on energy potentials, some studies show that shea butter cake can be used to generate biogas. There are, however, a few such studies, and they indicate that a high biogas yield could be obtained by combining shea butter cake with other substrates, specifically cow dung. Ofosu and Aklaku (2010) and Ofosu (2009) are two of these studies. Water, cow dung, and waste from shea butter processing were the main inputs in Ofosu's (2009) experiment. His experiment included specific ratios of cow dung to shea waste at three crucial stages: co-fermentation, "organic dry matter (ODM) concentrations," and "hydraulic retention times (HRT)". He summarised the findings of the study as follows:

> *The result of the experiments showed that process stability in anaerobic digestion of the shea waste could only be achieved through co-fermentation with cow dung in the ratio of 50:50 by volume at 7% odm concentrations at 30 days HRT. Anaerobic digestion of shea waste was therefore found to be feasible in the generation of methane* (Ofosu 2009, iii).

4.6 Challenges of production and uses of shea butter waste

According to Abdul-Mumeen et al. (2013), for every unit of shea kernels employed, 45 to 60 percent of waste is produced. This study's findings appear to be consistent with this estimate. Considering that the rate of extraction is 40% for modern technologies (see Figure 6), it follows that this sector would produce close to 60% of waste. Based on the findings of literature review concerning the uses of shea waste, engineering solutions were therefore discussed with processors considering the volume of waste, which roughly could be described as production inefficiencies. The discussions and solutions focused on how to use shea butter waste or cake to produce biogas and compost production—about uses of shea butter waste were identified in the literature, but the two were discussed with processors. The idea of biogas production was well received by those who participated in the survey; however, they indicated that the primary challenge would be the difficulty in obtaining both the necessary financial resources and the technical knowledge to get such projects off the ground. The type of biogas digester with a fixed dome would be suitable for the study area. The fact that this type of digester is being constructed by households that are beginning to construct digesters is one of the reasons for this recommendation. It was also observed that many young people are receiving training in the construction of household digesters, particularly those with a fixed dome. Further Internet research revealed that the fixed-dome structure is most likely the most prevalent in Ghana (an example in Figure 12 made available online by DAGLON-TECH, Ghana, is shown below). Consequently, there appears to be an abundance of skilled individuals available to construct digesters, the majority of which are of the fixed dome variety. Another important consideration is the fact this type of digester is considered more efficient and reliable (Lutaaya 2013).

Figure 9: A biogas digester under construction in Ghana (source: Taken online from DAGLON-TECH, Ghana).

Since the skills for the construction of biogas digesters in the study are primarily limited to the construction of household ones, additional training on the use of shea butter processing byproducts as feedstock would be required if this proposal were to be implemented. The two studies (Ofosu and Aklaku 2010; Ofosu 2009) identified on this topic can provide invaluable guidelines on how to empower local skilled persons to use shea butter cake in biogas production. There were also both open-ended and closed-ended questions used to evaluate other challenges of production. Processors ranked the cost of kernels, firewood (the primary energy source for frying kernels and boiling butter), and health risks highly in response to closed-ended questions. The least difficult challenge was a ready market for butter, indicating that there is a high demand for butter. However, this high demand for butter may be driving up the price of shea kernels, which is one reason why the price of shea kernels was likely rated as a significant obstacle. The lower ranking of storage costs may also be attributable to the high demand for butter, as this could indicate that processors do not have to worry about where and for how long to store butter. In a study conducted by Tanko (2017), processors ranked the poor quality of nuts and difficulty in obtaining loans as the greatest obstacles to shea butter processing, whereas labour costs and storage costs were ranked as the least significant obstacles.

Capital or production financing was identified as a significant obstacle in the open-ended questions. This had to do with the capital required to acquire shea kernels. Even though they produce on a small scale, they expressed interest in purchasing and storing kernels that would last until the following season. This, they suggested, would enable them to produce butter continuously throughout the year. Currently, most respondents indicated that they process the butter, sell it, pocket their profits, and then purchase shea kernels to repeat the cycle. As expected, however, kernel prices fluctuate, making it difficult for all processors to continue production throughout the year or to maintain reasonable profits. The next challenge they complained about was water, a challenge equally reported by Jibreel et al. (2013). The region in general is noted for the scarcity of water, which is frequently reported in the national media. They indicated that good quality water is important for the quality of butter; however, they are sometimes forced to use water from open sources such as dams and dugouts, which can affect butter quality.

4.7 Shea waste contributes to soil enrichment—potential for compost production

Investigations have also been done into shea cake's potential for soil fertility management, suggesting that it can be used for compost production. One of such studies that were found is Abagale et al. (2020, 98). Their research found that using shea butter waste slurry (SWS) as organic material improves soil fertility. They evaluated the effects of SWS on the primary and secondary nutrients of plants in two locations where SWS was applied. They sampled soil from fields measuring 25 m×40 m at depths of 0-30 cm and 30-60 cm for SWS-applied and unapplied soils using a one-way diagonal method. Their findings revealed that SWS application increased pH and increased EC from 41.15±3.89 to 155.5±83.4µS/cm in both locations. The SWS application also increased %N levels from 0.03±0.0 to 0.56±0.2%, at depths ranging from 0-30 cm, P concentration from 3.47±0.62 to 262.0±176 mg/kg, and K concentration from 21.9±2.39 to 231.6±98 mg/kg. Na levels increased from 0.46±0.09 to 2.81±1.0 meq/100 g. For a depth of 0-30 cm, Mg increased from 0.80±0.3 to 8.51±4.86

meq/100 g, while Ca increased from 1.6±0.07 to 6.3±098 meq/100 g at both study sites. In both study locations, soil %OM and OC increased from 0.58±0.01 to 10.94±3.95 and 0.34±0.11 to 6.36 ±2.29% , respectively for depths ranging from 0-30 cm.

4.8 Shea waste in poultry feed

A study conducted by Atuahene et al. (1998, 133) found that adding shea nut cake (SNC) to the diets of broiler chickens at concentrations up to 25 g kgy1 had no negative effects on performance. After analysing SNC, they discovered that it contained anti-nutrients like theobromine and saponin. They separated 240 commercial broiler chicks into four different groups. They provided them with three diets: one group with maize as the primary source of cereal, two groups with varying amounts of SNC, and a last one without SNC. Six weeks were dedicated to the experiment. Their findings revealed that including SNC in a diet has a negative impact on food consumption and weight gain. The amount of water and feed that was converted was shown to be significantly correlated with the level of SNC in the diet. The percentage of carcass dressing was greatly influenced by how much SNC was consumed. Reduced concentrations of red blood cells, hemoglobin, haematocrit, and total serum cholesterol were among the physiological changes observed in birds fed diets containing significant amounts of SNC.

4.9 Shea waste in the construction industry

A study has been conducted to determine whether shea waste can be utilised in the construction industry, specifically in the production of bricks. This was done by Adazabra et al. (2016). Their goal was to ascertain whether shea waste could be used as a brick-making additive, using a variety of instrumental analytical techniques. Their results were encouraging, which led them to advise the adoption of procedures for the widespread reuse of used shea waste materials in the shea industry in order to promote cleaner production (Adazabra et al. 2016, 335). The levels of significant replaceable cations such as K (2.11 wt%), Al (0.37 wt%), Ca (0.36 wt%), Si (0.35 wt%), and Mg (0.10 wt%), as well as various inorganic fluxes that promote clay brick formation, were among their key findings that led to their conclusions.

4.10 Challenges of production

Uncontrolled disposal of shea butter waste or cake was the most glaring problem at each and every processing facility visited. Typically, processing centres are situated in compact areas surrounded by residential and commercial structures. This has resulted in the accumulation of shea butter cake in these locations, as there are no waste management teams or trucks to transport the cake to landfills. The result is that most processors complained of constant conflicts with locals who find the accumulated waste and smoke from firewood to be offensive, repulsive, and a health hazard. Processors often expressly stated their wish for a permanent solution to the waste menace arising from their activities. Other challenges of production were assessed using both closed and open-ended questions. The results of this are in figures 9 and 10. In figure 9 (the close-ended questions), the least challenge was ready market for processed butter. This appears logical, given the previous exposition that by operating under an organised centre, processors have easier access to buyers. The most important challenges were the cost of kernels, firewood, health risks, and access to finance.

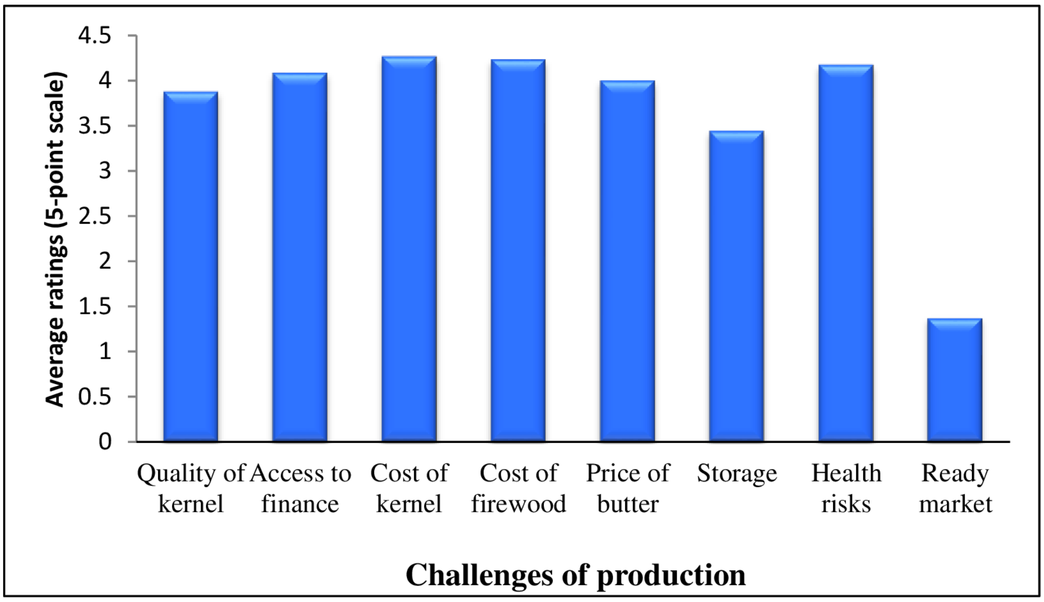

Figure 10: A bar chart showing the mean rankings of the challenges in shea butter processing.

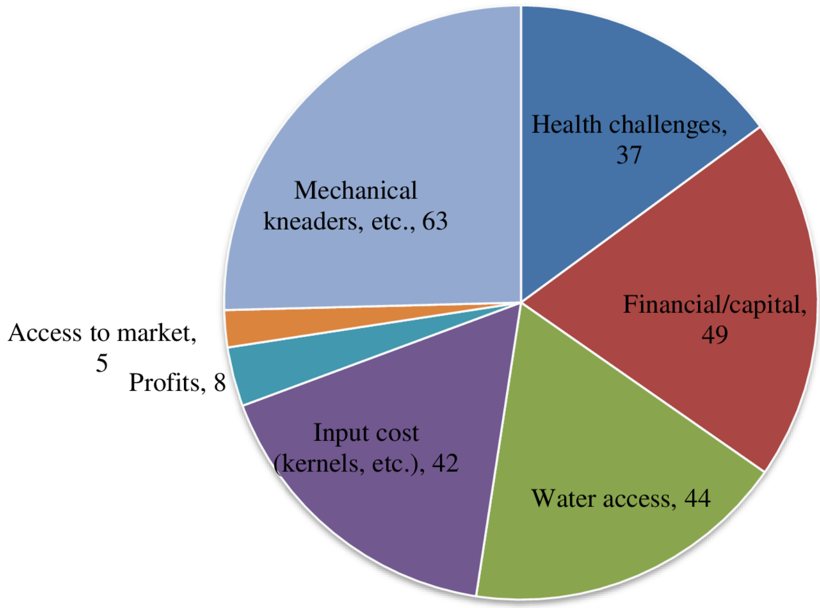

Figure 11: A pie chart showing the challenges in shea butter processing by frequencies (source: field data).

Seven different themes emerged from the open-ended question, and the results of this in figure 10 are identical to the one in figure 9. Only five processors mentioned access to the market as a challenge, a finding that is consistent with the one in figure 10. Sixty-three processors mentioned access to technologies that simplify some of the production processes. For processors who used indigenous technologies, there was a constant cry for modern technologies like drum roasters (they mostly indicated that they could not afford this improved technology) and mechanical milling machines. On the other hand, processors who already use these basic technologies expressed a need for more sophisticated equipment to improve their work. They frequently expressed the wish that mechanical technologies existed that could easily squeeze the oil from the shea kernels without requiring them to go through all the current production processes. Some of them had seen "bridge presses" in NGOs-organized demonstration centres, and they frequently expressed a desire for such programmes to be scaled up to improve their access to bridge presses. With the bridge press, processors need only moisten shea paste to a specific temperature and press it in the "bridge press to extract the oil" (Abdul-Mumeen 2019, 14).

4.11 Relationship between modern and indigenous shea butter processing technologies and profitability

Examined were various types of costs, revenues, and profits, as well as the determinants of profitability. This allowed for the examination of the relationships between technological application and the profitability of production, as measured by gross margins. Tables 8 and 9 display the descriptive statistics for processors who utilised modern technology versus those who utilised indigenous technologies. Because processors using modern technologies used more inputs, particularly shea kernels, their costs and revenue structures differed significantly from those of their counterparts using indigenous technologies and thus using small quantities of inputs. Comparing their costs and revenues would reveal little useful information; however, their return on investment (RIO), expressed in percentage terms, can be compared. The RIO for the modern technologies group is significantly higher than that of the indigenous technologies group, as the mean RIO for the former group is 42.39 % (±*SD* = 7.58 %) and for the latter, 33.12 % (±*SD* = 8.42 %), a difference of almost 10 %, indicating that, on average, for each unit of capital employed, the modern technologies group generated nearly 10 % more profit than the indigenous technologies group. Both groups of processors have extremely low fixed costs, which were determined by dividing the costs of fixed items by their estimated lifespan in weeks. The costs of drum roasters and electric or mechanical milling machines were not borne by the processors who operated from centralised facilities, so their fixed costs were also significantly lower.

Table 8: Cost, Revenues and Profits of processors who used modern technologies in GH₵ (N = 84).

Indicators	Minimum	Maximum	Mean (M)	±SD
Total Revenue	330.00	7678.00	1640.57	1030.02
Total Variable Cost	236.35	5370.00	1150.17	734.67
Total Fixed Cost	1.15	16.03	4.33	2.79
Total Cost	238.80	5386.03	1154.49	736.28
Gross Margin	93.65	2308.00	490.41	308.64
Net Income	91.20	2291.97	486.08	307.29
Return on Investment	21.13%	61.18%	42.39%	7.58%

M = Mean and*SD = standard deviation*

Table 9: Cost, Revenues and Profits of processors who used indigenous technologies in GH₵ (N = 19).

Indicators	Minimum	Maximum	Mean (M)	±SD
Total Revenue	154.00	396.00	237.95	66.12
Total Variable Cost	141.41	281.94	176.48	42.77
Total Fixed Cost	1.15	1.25	1.16	.02
Total Cost	142.57	283.10	177.64	42.76
Gross Margin	12.59	114.06	61.47	25.10
Net Income	11.43	112.90	60.31	25.11
Return on Investment	8.02%	43.15%	33.12%	8.42%

M = Mean and *SD = standard deviation*

It can be seen in the table 8 that there are wide variations in the distributions of total revenues and net income for the group that used modern technologies, based on a comparison of their means and standard deviations. This is partly due to the differences in the distributions of the scales of production in this group. For the other group in table 9, there was identical employment of inputs, particularly shea kernels, and as a result, the deviations in their revenues and net incomes appear much better

4.12 Determinants of profitability

This was determined by regressing a list of independent variables identified as crucial to profitability in the shea industry in the literature. The effects of technology use on profitability were especially important in this study. According to the findings in Table 10, there is a significant positive relationship between the use of modern technologies and profitability, as measured by gross margin (GM). Modern technology accounts for approximately GH 62 more in GM than indigenous technology, which is significant (P <.001). Also, significantly and negatively related to GM is the age of processors, indicating that older processors are more likely to experience GM loss than younger processors. The same was observed for cooperative union membership and paid labour - the units of labour that processors employed and compensated. In addition to technology use, the only significant and positive relationship observed was the quantity of kernels processed per week. Given the positive relationship between the use of technology and the number quantities of kernels processed this positive relationship is not surprising.

Table 10: The determinants of profitability (dependent variable, Gross Margin).

Variable	**B**	**Std. error**	**Sig.**
(Constant)	-8.260	23.823	.730
Use of Technology (yes = 1)	62.422	12.292	<.001
Age	-.864	.417	.041
Married (yes = 1)	-13.040	8.617	.134
Education (1 = low	12.575	14.763	.397
Additional occupation (yes)	3.302	8.087	.684
Experience (years	.499	.467	.289
Membership of cooperative (yes = 1)	-23.655	8.688	.008
Labour (not paid)	.125	2.112	.953
Records keeping (yes = 1)	2.393	8.775	.786
Quantity of kernel processed	3.288	.053	<.001
Labour (paid)	-49.021	2.756	.001

B standardised regression coefficient; sig. is level of significance.

4.13 Value addition

The assessment of value-added shea butter among local processors is not common, as evidenced by the literature. As a result, the question of value addition was exploratory. It was observed that shea butter was still produced, as it has been for ages, among local processors. The most recent and popular value-added activity was the addition of a particular plant root locally called *paaziegu* to the production processes to change the colour of shea butter from the traditional white or grey colour to a yellow one. Processors could not tell when this value-added activity began, but they indicated that they had known the technique for a long time but had only recently turned to producing yellow-coloured butter when commercial buyers developed a taste for it. The pictures in figure 12 show the contrast between value-added butter (left) and normal or common butter (right). According to processors, commercial buyers' preferences are shifting toward yellow-coloured butter. They argue that some users consider it as more visually appealing than traditional white or grey. While some processors only produced yellow-coloured butter when customers placed orders for it, others now simply produced it since it was becoming the preferred choice.

It must be pointed out that the use of *paaziegu* only changes the colour of shea butter, not the taste, texture, or any other thing. Besides this, processors purposefully followed through with some measures during the production processes to obtain the right quality of butter. They indicated that quality butter is a function of quality kernels and optimally roasted kernels, among others. They therefore made sure that they hand-picked defective kernels before processing. They had no instrument to determine when crushed kernels were optimally roasted. They relied on experience, while others simply grabbed a few kernels while they were roasting and listened to the sizzling sound it made. They were unanimous that they could tell when kernels were properly roasted from these sounds. Others mentioned the addition of good quality water, prolonged heating of butter, and a generally clean production environment and equipment as keys to extracting quality butter.

Figure 12: Shea butter with yellow (left) and white/grey (right) hues.

5 Discussion

The purpose of this study was to compare the efficiencies of modern and traditional shea butter production techniques, as well as the uses of shea butter waste, profitability, obstacles, and value addition in Ghana's shea butter production. The research was conducted specifically in the northern region of Ghana and in three main locations. Utilizing mobile technologies and field notes, data was collected. In addition to the four primary questions that guided the research, there are a few observations that warrant discussion.

Most shea butter processors were discovered to operate within NGOs-initiated and processor-run processing centres. In addition to providing relatively inexpensive space and equipment for use by processors, this innovation brought about additional advantages. One is the controlled and centralised disposal of production waste, which is beneficial for humans and the environment. The processing of shea butter is associated with a variety of environmental impacts resulting from the discarded shea residue and wastewater, which, among other things, alter soil structure and inhibit plant growth (Jibreel et al. 2013). The centralization of production offers a significant chance to aggregate this waste more effectively for the advancement of suggested engineering solutions, like the large-scale production of biogas and shea butter briquettes. The centralization of processing activities also served social purposes, as it brought women together daily to engage in productive activities and discuss social issues affecting them. However, centralization is only suitable for nearby processors and not those who are located far away.

One of the surprising demographic findings regarding processors was the presence of men in the processing industry. In rural livelihoods studies, the processing of shea butter and related activities have been referred to as "women's gold" (Pouliot 2012). Thus, the involvement of a man was unexpected. This may indicate a shift in attitudes toward gendered activities in production regions. There may also be a decline in productive opportunities for men, which forces men to cross gender lines. Regardless of the reason, it was observed that the participation of men in shea processing could be an important step towards increasing shea butter production in Ghana. The reason for this is that the man in this study used the most units of shea kernel-about 850 kg-due, most likely, to the fact that he controlled more financial assets than the average female producer. Also significant was the observation that most processors are older and married. Further, it was observed that young women participated in the purchase and further processing of shea butter. This is part of a recent trend of young women in Ghana, especially college graduates, engaging in entrepreneurial endeavours. Particularly for shea butter, it is now commonplace for aspiring entrepreneurs to market their products on major social media platforms.

5.1 Relationships between modern and indigenous shea butter processing technologies and shea butter output

This question was investigated in a variety of ways to determine which of the technologies is the most efficient. This study employs a simple production efficiency function, operationalising efficiency by analysing the absolute quantities and quality of shea butter output relative to inputs, specifically shea kernels. The first was the observation of extraction rates of 40.21% for modern technology and 34.85% for traditional technology. Similar findings were reported by Jasaw et al. (2015). Modern technology was operationalised as the use of improved roasters and electric or mechanical milling machines, whereas indigenous technology was defined as the exclusive use of time-tested traditional technologies, all of which are described in the methodology section of the study.

A significant and positive correlation was also found between the use of modern technologies and the extraction rate, number of kernels utilised, and amount of butter. Since this did not reveal the precise changes in the units of butter produced because of changes in technological units, a simple bivariate and multiple regression analysis was conducted. The regression analysis also allowed for the isolation of the effects of other known factors that affect extraction rates to determine the true effects of technology use on extraction rates. The effect sizes of technology use remained large, positive, and statistically significant in both models. As reported by Jibreel et al. (2013), it was anticipated that processing experience would be associated with greater extraction; however, this expectation was not met. Another expectation that was not met is the quantity of labour units utilised. This returned a negative beta coefficient, indicating that this sample of processors may employ more labour than necessary; however, the insignificance of the correlation renders this conclusion inconclusive.

The quality of shea butter constitutes the final technology-output relationship examined. Taste, texture, colour, and odour/aroma of shea butter were used as quality indicators. The production process and the quality of the kernels determine the quality of butter. The method that was used to evaluate this was a practical one, and it consisted of providing processors with samples of butter that had been determined to be of high quality for them to compare with what they had produced within the previous week before responding to the quality questions. According to the findings of a survey conducted by Honfo et al. (2012), most shea butter manufacturers and consumers consider colour to be the single most important factor in determining product quality (more about colour will be discussed in another section). They also discovered that while 45% of users placed importance on the smell of the product, 49% placed importance on the texture.

The findings by Honfo et al. (2012) are comparable to those reported in this study; however, the methodology of this study focused not on what processors considered to be the butter of the highest quality, but rather on the quality of the butter that the processors themselves produced. In general, processors who utilised modern technologies gave a higher rating to the quality of their butter as compared to their counterparts who utilised traditional technologies. It is important to note that other factors, such as the duration of processing and the conditions of storage, among other things, also affect butter quality (Bup et al. 2008). As a result, the findings relating to butter quality may not only be attributed to the utilisation of technology.

5.2 Relationship between modern and indigenous shea butter processing technologies and profitability

The profitability of production was determined by collecting and analysing data from processors on the different types of costs (fixed and variable costs) and revenues. Profitability analysis also enabled the investigation of the specific relationships between technology use and profits. The allocation of the cost of fixed inputs over their useful lives resulted in lower total fixed costs (TFC) for processors in general. The profits processors (net income) make are therefore largely driven by their variable costs (VC), of which the quantities and costs of shea kernels account for the greatest share.

A comparative analysis of returns on investment (ROI) showed that processors who use modern technologies make about 10% more profits on every unit of money (GH₵ 1) invested than those who employ solely indigenous technologies. This finding appears consistent with the finding that about 40% of processors make an average profit of between ten Ghana pesewas (GH₵ 0.10) and 50 Ghana pesewas (GH₵ 0.50) on every GH₵1 invested in shea butter processing and marketing of shea butter (Deng et al. 2017, 26). Gross margins (GM) of processors who used modern technologies were also higher than those who used indigenous technologies; however, the GM was driven by total revenues, which were higher for the former group than the latter, primarily because they employed more units of shea kernels, resulting in a higher butter output and, thus, higher revenues. Just like the GM, the net incomes of both groups of processors were positive, indicating that they all make profits.

The study also found that technology utilisation is a determinant of profitability, with processors earning approximately GH₵ 62 per unit of technology employed. A unit increase in age was also associated with an approximately 86 Ghana pesewa decrease in GM. Similar negative associations were discovered between marital status (married), membership in a cooperative union, and units of labour for which payment was received. Experience (number of years processors have been engaged in shea butter processing) was found to be significantly and positively related to GM in a study by Kodua et al. (2018); however, in this study, this positive relationship was observed but was not statistically significant.

5.3 Value addition

The observed value-added activity was the transition from the production of what could be described as white or grey butter to butter with a yellow-hue. It was discovered that the processors dried and ground a plant root known in the area as *paaziegu*, which they then incorporated into the butter cream and boiled. After boiling the oil, they simply poured it into storage containers and disposed off the remaining root residue. The finished product of this procedure is butter that has a yellowish hue. It was obvious that this production method is gaining traction and is being supported by customers who are looking for variety in butter. Honfo et al. (2012) discovered comparable results in a study conducted in Benin, West Africa.

They report that yellow-coloured butter was the most preferred butter among end users, and as a result, processors add the roots of *Cochlospermum tinctorium* when boiling butter cream. They also report that during the rainy season, processors produce naturally a butter that is a greyish colour. This occurs because of the shea kernels not being dried properly. There were attempts to get the scientific name for the *paaziegu* identified in this study, but those attempts were unsuccessful. Because of this, it has not been possible to determine whether it is the same as the *Cochlospermum tinctorium* that is mentioned in Honfo et al (2012).

6 Conclusions

The primary objective of the study was to compare the efficiencies of indigenous and modern technologies in the production of shea butter in Ghana and the uses of shea butter waste, in addition to evaluating other factors including profitability, obstacles, and value addition. Modern technology was operationalised using drum roasters and mechanical or electric milling machines in three critical stages of processing: crushing kernels into grits, roasting gritted kernels, and milling roasted grits. Some processors in this study still used indigenous technologies at these stages, which included roasting kernels in open pans, pounding kernels into grits with mortars and pestles, and grinding roasted grits with manual and labour-intensive grinding stones. As part of the investigation, three major locations in the country's northern region were examined. Utilizing mobile technologies and making field notes, data was collected in the field. The data was subjected to a variety of statistical analyses, some of which included descriptive statistics, correlation analysis, regression analysis, and profitability analysis.

The study revealed that modern technologies produce a greater quantity of shea butter than traditional technologies. This was determined by comparing the extraction rates of processors utilising modern technologies to those utilising indigenous technologies. It was also observed that processors who utilised modern technologies rated their shea butter as having a higher quality, as measured by texture, flavour, colour, and odour. Using correlation analysis, the relationship between technology use and butter extraction rate was evaluated further, and positive relationships were observed. In bivariate and multivariate analyses, technology use positively predicted extraction rate with beta coefficients of 5.357 and 4.987, respectively. Based on these findings, the study concludes that the identified modern technologies are more efficient than the indigenous technologies in the processing of shea butter.

Several production obstacles were also identified, and they appeared consistent with several previously conducted studies. One of these challenges is the growing shea butter cake and its foul odour, which has a negative impact on the environment and residents' health. As a result, an engineering solution in the form of biogas production using the cake as a raw material was proposed and accepted by processors. The proposed solution was based on the findings of a literature review, where four uses of shea butter waste was identified. However, it was clear from the discussions that such a project would be difficult due to financial and technical constraints.

The study also discovered that the most difficult aspects of production were the high cost of kernels, the high cost of energy, and the health complications caused by the smoke and heat associated with processing, using both closed- and open-ended questionnaires. The cost of storage and marketing for processed butter were the least difficult aspects of production. In an open-ended survey, access to capital and the availability of clean water were also cited as significant obstacles. In general, it appears that most production challenges are beyond the control of processors, necessitating the intervention of the government and charitable organisations to be resolved.

Additionally, a profitability analysis represented by gross margins (GM) was also conducted. The observed relationship between technology use and profitability was positive, and its beta coefficient (62.422) was the highest of any of the other variables included in the study. The cost and revenue analysis also revealed that processors utilising modern technologies reported an average return on investment (ROI) of 42%, whereas their counterparts utilising indigenous technologies reported a ROI of approximately 33%, indicating that processors utilising modern technologies are receiving better returns on their investments. Nonetheless, the processing of shea butter generates profits in the study area, as evidenced by the positive values for net incomes in both groups, but the number of profits could be increased through the application of more advanced technologies.

Finally, the study investigated the addition of value during shea butter processing. This question appeared to be unexplored in prior research, which may be because butter has been produced using the same methods for decades and its nature and quality have remained unchanged. The recent shift in consumer preference for butter with a yellow hue is a phenomenon that processors are eager to accommodate. Aside from this value-added activity, processors strive to produce butter of consistent quality to the greatest extent possible. They accomplish this by, among other things, carefully hand-picking bad kernels before processing, heating butter for an extended period, using clean equipments, and frying gritted kernels to perfection, which they appeared to have mastered over the years.

6.1 Limitations of the study

A limitation of the study is the operationalisation of modern technology, such as the use of drum roasters and milling machines. The fact that these processors continue to manually churn, heat, and extract shea butter suggests that their classification as "users of modern technology" should be interpreted with caution. In addition, there was a significant difference between the number of respondents who utilised indigenous technology and those who utilised modern technology. The former group was only one-fourth the size of the latter; as a result, any study that includes a comparable number of respondents from both groups may uncover results that differ from those reported. In addition, these two groups did not come from the same communities; the indigenous technology users came from remote villages, whereas their counterparts lived in urban cities.

6.2 Recommendations and directions for future research

The study has demonstrated that the use of modern technologies in the processing of shea butter results in an increase in extraction rates and butter quality. However, it is evident that not all processors have access to these fundamental technologies. To address this issue, it is crucial for the government of Ghana and financial institutions to devise means of expanding women's access to capital so they can acquire these fundamental technologies. Because some stages of shea butter processing are still performed manually, the introduction of more advanced technologies that eliminate all human effort in the butter-producing regions would provide significant relief to processors. Utilizing shea butter waste as an input material in biogas production, the engineering solution to the problem of shea butter waste accumulation, would require some capital investments, which the processors cannot afford. For such a proposal to become a reality, government and charitable organisations must lend their support.

It appears that men are also entering the shea butter processing industry, which is good news considering the potential capital and output their participation would generate. However, there are unanswered questions in the literature regarding the participation of men in the processing of shea butter. The first question is: why are men not involved in the production of shea butter? Would the participation of men result in the displacement of women in an activity that was previously considered a women's domain? What would this mean for the economic empowerment of women in shea-producing regions? In addition, it was observed that some consumers preferred butter with a yellow hue, which influenced changes in production strategies; however, processors were unable to explain the reasons for the shifts in consumer preferences, presenting opportunities for future investigation. Similarly, the use of the local plant roots known as *paaziegu* as additives to alter the colour of shea butter paves the way for additional research. First, the tree's scientific classification must be determined. And secondly, it is necessary to determine whether the plant's chemicals are toxic to humans.

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8 Appendix

1. Questionnaire
2. Name of Community………………………..
3. Age of respondent……………………….
4. Gender of respondent Male [ ] Female [ ]
5. Marital status Married [ ] Single [ ] Widowed [ ]
6. Household size……………………..
7. What is your level of education?………………………….
8. What is your occupation besides shea butter processing?...............................
9. How many years you have been engaged in shea butter processing?...........
10. Do you produce under an established processing shea center? YES [ ] NO [ ]
11. If YES, what is the name of the centre?.................................
12. Where do you get the shea kernel you process into shea butter?..................................
13. What is the distance (Km) from your home to where you buy your shea kernel?...................
14. What is the quantity of the shea kernel you processed in the last week?.........................
15. What is the quantity of shea butter you extracted from the shea kernel you processed in the last week?................................
16. What was the cost of transporting the shea kernel to the house?............................
17. What was the cost of transporting the processed shea butter to the market for sale/customers?......................................
18. How many people helped you to process the shea butter and received payment?...........................
19. How many people helped to process the shea butter and did not receive payment?...
20. What is your source of money invested in the shea butter processing? Personal Loans [ ] Loans from a bank [ ] Gift/donation from a family member or philanthropist [ ].
21. Do you keep records of your activities? YES ( ) NO ( )
22. Do you belong to any women's cooperative or (shea) group? YES ( ) NO ( )
23. What do you use to Crush your nuts into grits? (This could be an electric crusher; grinding mill; mortar and pestle etc.)……………………………

24. What do you use to roast the crushed shea kernel? (This could be equipment like a drum roaster; frying pan or pot etc.)……………………………………………………
25. What did you use to mill/grind the gritted shea nuts into paste?...
26. How is the fire setup for roasting shea kernel? (The setup could be an electric stove/roaster stove; three stones placed in a circle with a pot or pan placed on top; etc.)………………………………….
27. For those who used frying Pans, what is the Cost of a Frying Pan?.....................................
28. Cost of other fixed ibputs…………………………………………
29. For those who used a drum roaster/roaster stove or any other equipment, what is their cost?..
30. How much did you spend on firewood in the entire stages of the production process?..............
31. How much did you spend on water in the entire stages of the production process?...................
32. amount paid for the service?..
33. What are the total expenses you incurred for grinding/milling through an electrical/mechanical machine?.......................................
34. How much did you spend on market tolls?..............................
35. On a scale of 1 to 5, how would you rate poor quality of shea kernel as a challenge to shea butter processing?.......................
36. On a scale of 1 to 5, how would you rate access to a loan as a challenge to shea butter processing?...............................
37. On a scale of 1 to 5, how would you rate the cost of shea kernel as a challenge to shea butter processing?................................
38. On a scale of 1 to 5, how would you rate the cost of firewood/electric bill as a challenge to shea butter processing?.......................
39. On a scale of 1 to 5, how would you rate the cost of shea kernel as a challenge to the shea butter process?................................
40. On a scale of 1 to 5, how would you rate the price of shea butter as a challenge to shea butter processing?......................................
41. On a scale of 1 to 5, how would you rate the storage/packaging of shea butter as a challenge to shea butter processing?..............................

42. On a scale of 1 to 5, how are the health risks associated with shea butter processing a challenge to you?..............................
43. On a scale of 1 to 5, how is ready-market for shea butter a challenge to you?.................
44. On a scale of 1 to 5, how does the odour of the shea butter you produced in the last week compare with what is considered the best odour of shea butter?..............................
45. On a scale of 1 to 5, how does the taste of the shea butter you produced in the last week compare with what is considered the best taste of shea butter?................................
46. On a scale of 1 to 5, how does the texture of the shea butter you produced in the last week compare with what is considered the best texture of shea butter?..............................
47. On a scale of 1 to 5, how does the colour of the shea butter you produced in the last week compare with what is considered the best colour of shea butter?.......................
48. What measures do you take to improve the quantity and quality (odour, texture, taste, and colour) of shea butter?
49. What other challenges do you face in shea butter processing?