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Article

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Fundamentals of shea butter production; input–output analyses and profit maximization in Northern Ghana

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ABSTRACT

Shea butter is a vital commodity in the global economy, engaging millions of women across the African shea belt, as income directly or indirectly in the value chain. The shea kernel is obtained from processing fresh shea fruits and further processed into shea butter. Manual and semi-mechanized methods are employed in processing shea kernel into butter. Major inputs are; kernel, water, energy, and time and outputs are; shea butter and wastewater. Focus group discussions and individual interviews and material flow analysis were applied to cross-sectional data generated from five Shea Butter Extraction Women Cooperative centres in the Northern and Upper West Regions of Ghana. Results showed that with an input of 86.3 ± 1.88 kg of the kernel, 305.2 ± 24.3 L of water, 49.7 ± 7.2 kg of fuelwood and 15.11 ± 1.9 h, the output was 29.7 ± 2.39 kg of shea butter, 46.86 ± 13.8 kg of shea residues and 202.3 ± 3.95 L of wastewater (effluent). The study recommends more efficient use of inputs to ensure profit maximization. Processing at the cooperative level coupled with sustainable value addition promotion, could guarantee security and increased income. Further research on the chemical composition of shea waste will be required for possible reuse.

Introduction

The shea tree is a wild indigenous tree exclusive to Africa and is increasingly being managed in farmlands while found also in the Savanna parklands. It usually grows to an average height of about 15 m with profuse branches and a thick waxy and deeply fissured bark that makes it fire resistant (Fobil, 2007; SNV, 2011). The shea tree grows wild in the dry Savannah belt of West Africa from Senegal in the west to Sudan in the east, and onto the foothills of the Ethiopian highlands. It occurs in 19 countries across the African continent, namely Benin, Ghana, Chad, Burkina Faso, Cameroon, Central African Republic, Ethiopia, Guinea Bissau, Cote d'Ivoire, Mali, Niger, Nigeria, Senegal, Sierra Leone, Sudan, Togo, Uganda, Zaire and Guinea (Fobil et al., 2002; Bondé et al., 2019). In Ghana, it occurs extensively in the Guinea savannah and less abundantly in the Sudan Savannah (SNV, 2011). Two varieties of shea have been identified as the *Vitellaria paradoxa* and *Vitellaria nilotica*. The former is found in West Africa whereas the latter is indigenous to East Africa, particularly Northern Uganda and Southern

Sudan (FAO, 1988; Ferris et al., 2001; Nasare et al., 2019).

In Ghana, the shea tree occurs almost in the entire area of Northern Ghana (about 77,670 km²) and supports the livelihood of approximately 900,000 rural women involved in the sector of Northern Ghana (SNV, 2011). Selected patches of dense parklands of shea trees can be found in areas around Western Dagomba lands, Southern Mamprusi, Gonjaland, Eastern parts of Nadowli, Sissala lands and Western parts of the Upper West Region especially around the sanctuary areas of Wechiau (Graphic Showbiz, 2021; Fobil, 2007). There is also sparse shea tree cover found in the Brong-Ahafo, Ashanti, Eastern and Volta regions in southern Ghana (FAO, 1988a; Fobil, 2007; Hatskevich et al., 2011; SNV, 2011). Estimates of tree population vary and there are no available statistics on exact numbers. However, according to Adams et al. (2016), the shea sector employs about 85 % of rural women and this contributes about 70 % of the income of rural households in Wa Municipality and its environs.

Shea butter production is made up of local, semi-mechanized and automated processes in Ghana. The shea industry generates employment

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and income for about a million rural women in northern Ghana involved in picking nuts and marketing processed shea kernel and shea butter. Major shea activities involve picking or gathering fruits and nuts, processing nuts into butter, and distributing and marketing shea commodities. Shea butter entrepreneurs, mostly women, sell to both domestic and international markets. Processing shea commodities has attracted different kinds of support from export companies, NGOs, development partners and the government. Shea commodities (shea kernel and butter) have become tradable and have entered the international market because of their export potential.

According to the American Shea Butter Institute, there are about twenty-one (21) uses of shea butter. Major uses include local consumption of shea butter as food, use for cosmetics, soaps and detergents, medicines, and for cultural/religious purposes. The major industrial and commercial uses are cosmetics and pharmaceuticals. In many countries such as Japan, the United Kingdom, Germany, and the Netherlands shea butter is considered a valuable product for natural/luxury cosmetics such as skin creams, soaps and shampoos because of its moistening/hydrating, protecting and softening properties (Schreckenberger, 2004; Basit, 2010; Jasaw et al., 2015; Abdul-Mumeen et al., 2019). Shea butter is a major source of economic sustenance for women because shea butter processing (handcraft butter) remains in the hands of rural women especially those in northern Ghana (Sualihu, 2019). It is argued that the profit margins of those engaged in handcraft butter processing are very marginal. Despite the numerous benefits derived from shea butter, many have questioned the profit generated by rural women into shea butter production business (Issahaku, 2012; Laube, 2016). The profitability is affected by many factors, some of which may be outside the control of the women, while others are due to inefficiencies. Many studies have only concentrated on the contribution of shea to food security (Quaye,

2008; Owusu et al., 2011; Tsiboe et al., 2016), shea and livelihood improvement (Pouliot, 2012; Adams et al., 2016), energy use (SNV, 2006), shea marketing (Ferris, et al., 2001; Addaquay, 2004; SNV, 2006), women participation in shea value chains (Kent and Bakaweri, 2010), and shea and food security (Akrasi et al., 2021).

Others have also argued that the inputs required in the traditional hand-crafted butter and the waste generated through shea butter processing make the entire enterprise unprofitable (Lovett, 2018). In addition to establishing very critical baseline information on many of the factors of production that have not attracted the attention of actors and researchers, the study also established the quantity of all inputs used in the processing of butter and all outputs resulting from that. The study also assessed how these influence revenue levels.

Materials and methods

Study area description

The study was conducted in the Upper West and Northern Regions of Ghana. From these regions, five (5) well-established Women Shea Butter Cooperatives in Bognyili, Kukuio and Sagnarigu (Northern region), and Naawie and Suke (Upper West region) were selected (See Fig. 1). The selection of these 5 cooperatives was out of 11 cooperatives under the Community Commerce Shea butter Project which produce for both local and international markets with regular orders to produce shea butter for over 5 years consistently (SNV, 2011; Lovett, 2018). A project implemented by SNV with funding from Sundial Brands through The Sofi Tucker Foundation. The 5 cooperatives produced 80 % of the supply and hence were working regularly. For ethical reasons, the names of the five selected sites were branded as A-E (See Fig. 1).

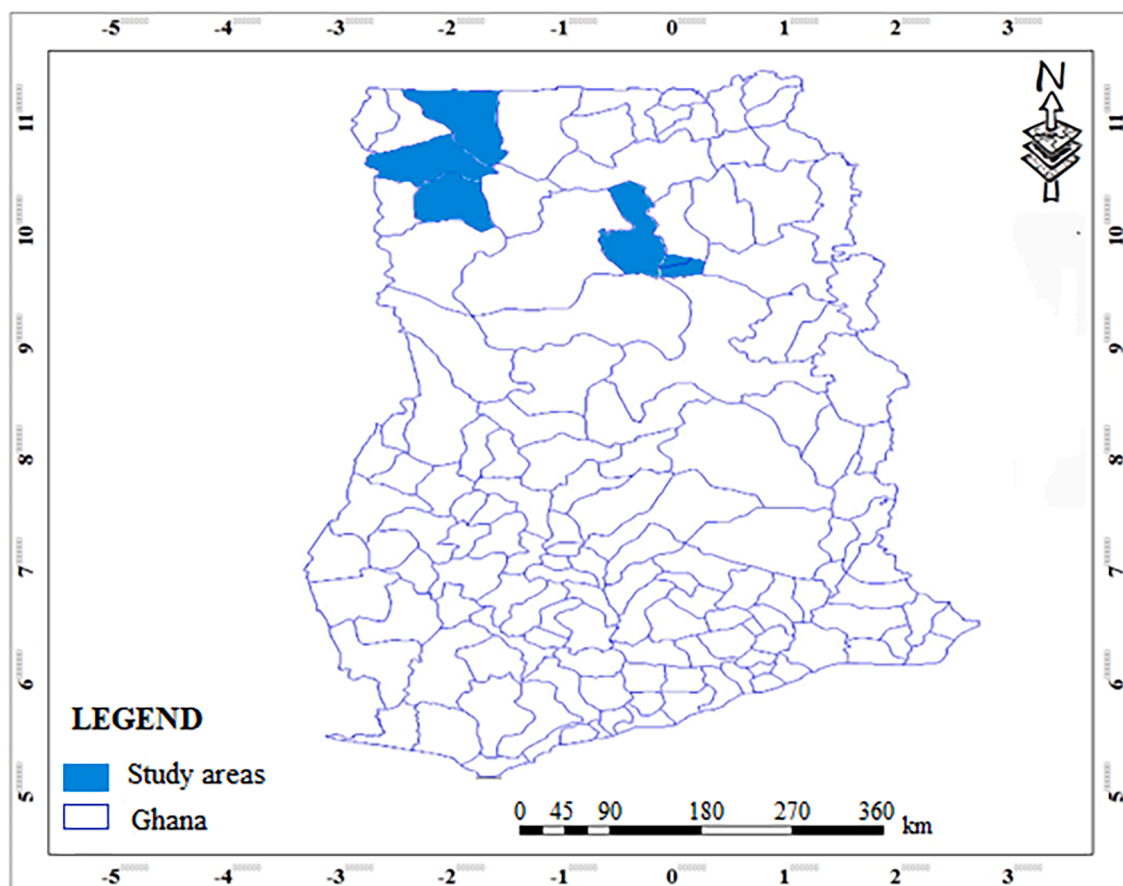


Fig. 1. Map of Ghana indicating the various districts where the study was conducted.

Sampling

Unlike previous studies that relied on only one form of instrument, the methodological approach in this study relied on scientific field experimentation, focus group discussions (FGDs), and individual interviews on shea butter production. The study was conducted from January to April 2019. The data and views obtained from these three sources enabled triangulation for better reliability of the exact parameters. The primary data was collected from the field experimentation in which the researchers participated in the shea butter-making process, inventoried all inputs, quantified all inputs and measured the outputs as well. FGDs were also conducted with a control group of at least 8 women in each study Centre. These were active shea butter processors in the cooperatives and were purposely selected. After this, the individual *Makazie* (5 of them) were purposely selected for an expert interview using an open-ended questionnaire guide to gather qualitative responses. The information generated in FGDs and the expert interviews helped to verify and validate the findings generated from the experimentation process.

Construction of setup

This study employed the use of materials including shea kernel, water, a graduated measuring cylinder (1000 ml), a 270 L drum, a 34 L cylinder locally known as 'garuwa', a 12 L plastic bucket, a 70 L plastic container, a platform weighing scale, an electronic scale, a roaster, an energy-saving stove, aluminium basins (4) and cooking pot, and a mortar and pestle. In the input and output systems, the amount/volume of shea kernel, water, fuelwood and time/labour, and shea butter, wastewater and dry cake were respectively measured. Fig. 2 presents a descriptive pattern involved in the extraction of shea butter.

Preparation of materials

Weighing, sorting, washing and cleaning shea kernel (raw material)

For this study, 87 kg of unsorted shea kernel and four women (labour) to process it as this was the practice at the cooperative centres. Thus, each bag of kernel was processed by a team of 4 women. The weighing was done at the processing centres twice for every item. The average weight of the kernel was then calculated. The weight of each sack was also compensated for. The time used in this activity was recorded. Sorting of the kernel is done to ensure that only the finest ones are used in the processing of butter. The kernels were sorted by a team of 4 women who manually sort out all foreign materials and dark and burnt kernels. These materials were mainly stones, shells of the kernels, crop residue and discoloured kernels. The total time used in the sorting was noted. After sorting out foreign materials, the kernels were then washed. The washing involved turning/mixing the kernel in the water against each other to remove dirt and other foreign materials on the surface of the kernel. The amount of water used for washing the kernel was recorded with the aid of the graduated measuring cylinder. The weight of the kernel before and after washing was also determined. The dirty water that remained after washing was measured and the volume was taken with the aid of the 1000 ml measuring cylinder. At all the study sites, this water was not reused. After washing, the kernels were allowed to dry.

Crushing and roasting

The processing of butter requires that the kernel be crushed. There are two methods used in the crushing of kernels. The manual and the mechanical methods. Manual crushing involves crushing kernel into grits using a 'dum-bell shaped' wooden structure against a clean hard surface. Kernels can also be crushed using mortar and pestle. For this study, the kernels were crushed mechanically which involved using an electrical crusher. The weight of the crushed kernel was taken and the total time used in this activity was recorded as well. The cost of crushing

was also recorded. Roasting requires the use of firewood. The quantity (weight) of the firewood used and the cost of the roasting process was recorded. The roasters used were the metal frying chamber type for this study. However, in some centres, the women use aluminium pots on local tripod stone stoves. The time spent roasting the crushed kernel was recorded (See Table 1).

Milling/grinding into paste and kneading/beating

This is the act of grinding the shea grits (crushed kernels) into a paste. The milling was done in an electric-powered grinding mill. The time and cost for milling were recorded. The energy consumed was recorded by taking the initial and final reading on the power metres installed whilst the diesel consumed was also measured and cost added. Kneading is the most critical stage in shea butter processing. It is the act of beating the paste in a randomized pattern and pace with the intermittent introduction of hot and cold water to obtain the crude white butter. The volumes of hot and cold water used in the whole process were measured. It is good to note that the cost of energy (firewood, kg) used for heating water for the kneading is captured in the quantity of wood used in roasting (Table 3). The wood used in roasting was continued in use to heat water for the kneading stage as well. The time spent was recorded. After the kneading and extracting of raw butter for cooking, the wastewater generated from the kneading was recorded. The weather has profound effects on the outcome of shea butter kneading. It influences the rate of kneading and determines when to apply hot or cold water.

Boiling of crude butter paste and filtration

Boiling is heating the crude white butter to obtain the liquid oil. The firewood and shea cake used were weighed. The yellow oil at the top was scooped into a different pot and boiling continued. The dark-brown residue (shea residue) underneath the pot after the top clean oil is scooped out. Boiling was continuous with the addition of traces of the crude butter obtained after washing the basins which were used for kneading. This is known as 'mandugu' in the Dagbanli language which means re-boiling. The time was recorded. The oil is allowed to settle for about an hour to cool and then filtered. The time it takes to achieve cooling was recorded. The volume of the final product which is the shea oil was measured. The residue (dark brown cake) generated beneath the cooking pot is scooped out and weighed, while the oil that still contains some residue is filtered after a few minutes to an hour of cooling to prevent the solidification of both the oil and the residue together. The time used in this process was recorded.

Solidification/cooling and packaging

The filtered oil is then left in a pan in a clean open airy place to cool and become semi-solid. Solidification starts the following day depending on the weather conditions. Solidification is enhanced with the occasional stirring of the liquid oil in a clean room with enough ventilation to speed up solidification smoothly. The weight of shea butter after

Table 1
Summary of inputs used for processing a unit of shea kernel (86 kg) into butter.

Processing cooperatives	Inputs required in processing a unit of shea kernel			
	Shea kernel (kg)	Water (L)	Fuelwood (kg)	Time (H)
A	85.6	273.6	48.0	16.93
B	86.4	302.0	45.0	16.57
C	89.5	334.0	41.5	15.65
D	85.0	292.5	56.0	13.90
E	85.0	324.0	58.0	12.51
Average/SDEV	86.30 ± 1.88	305.2 ± 24.3	49.7 ± 7.2	15.12 ± 1.9

*SDEV- standard deviation values.

Table 2

Volume of water at various stages of the shea butter processing in litres.

Type of wastewater	Quantity (litres)
Water used to wash shea kernels	58.9 ± 15.8
Volume of hot water used during kneading to rinsing	32.72 ± 16.6
Volume of cold water used during kneading to rinsing	213.6 ± 33.9
Total volume of water used (TVW)	305.2 ± 24.3

Table 3

Firewood quantities used for shea butter processing and cost of firewood.

Processing centre	Firewood for roasting and heating water (kg)	Firewood for boiling (kg)	Total firewood (kg)	Firewood cost (GH¢)
A	14.0	34.0	48.0	9.7
B	16.5	28.5	45.0	5.5
C	8.0	33.5	41.5	9.7
D	17.1	38.9	56.0	8.0
E	26.0	32.0	58.0	4.0
Average	16.32	33.38	49.7	7.4

solidification was taken. The time spent was also recorded. The shea butter was scooped out neatly into a transparent polythene bag in a carton box that weighed 25 kg. The shea butter is usually packaged into a desired final packaging chamber before solidification so that the solidified butter can assume the shape of the desired container. The container is then sealed with sellotape. For the local market, it is moulded into balls for sale.

Analysis of shea butter, wastewater and cake

Analyses of all input quantities and the duration of each process were recorded. The Cost-Benefit Analysis, (CBA) was carried out using the cost of the inputs and the revenue from the outputs obtained after-sales. Data gathered on all parameters were analyzed using Microsoft Excel and Statistical Package for Social Sciences (SPSS) V.18.

Results and discussion

Inputs quantification in the shea butter processing

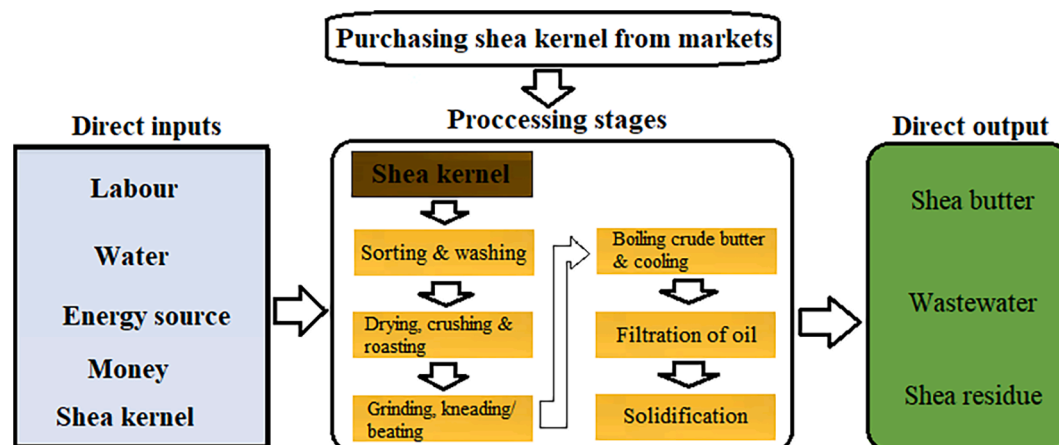
The production of shea butter requires the following inputs: shea kernel, water, firewood, power (electricity), labour and money at

various stages of the processing. Fig. 2 presents the summary of the input quantities used. The quantity of shea butter produced from the five-cooperative shea butter processing centres showed an average of 86.3 ± 1.88 kg of shea kernel to 29.7 ± 2.39 kg of shea butter. There were differences in the weight of each unit of shea kernel to shea butter produced among the five cooperative centres (Supplementary material Fig. 1). This could be attributed to the difference in packaging/fill-up in the various sacks, and also the quality of shea kernels. Centre C recorded the highest weight of shea kernel and the highest shea butter extracted while Centre E recorded the least in kernel and butter weight (supplementary materials Fig. 2). However, this trend was not recorded in the case of the other three centres. This suggests that the quantity of butter extracted was not proportional to the amount of shea kernel used. This could be attributed to the following factors; the maturity of the fruit, the par-boiling to drying of kernels and the entire process of crushing, kneading and crude butter extraction. However, statistical analyses of variance (ANOVA) showed that there was no significant difference between the weight of shea kernel and butter produced from the five centres ($p < 0.05$). Thus, the study suggests that an average unit bag of shea kernel weighing 86.3 ± 1.88 kg yields 29.7 ± 2.39 kg of shea butter respectively (Table 9).

The results (supplementary material Fig. 2) showed that for one bag of shea kernel processed, the shea butter obtained averagely is about 35.61 % i.e., for 1 kg of shea kernel 0.36 kg of shea butter is produced. This fraction of shea butter obtained is influenced by the quality of the kernels, which mainly depends on the maturity of the fruit, par-boiling, storage and other handling processes, the cooking and drying temperatures, the method; traditional, centrifugal, and Soxhlet extraction affect the yield (Kar and Mital, 1981; Dongmo et al., 2014). The yield obtained from the study ranged from 32.94 % to 37.50 % using the traditional method of extraction which is similar to 20–28 % recorded by Coulibaly et al. (2004). This suggests that the yields from the various processing centres were meeting industry standards.

Water quantification at various stages of processing

Water is very essential in the entire process. Water is used for the initial washing of the kernel. It is again used for the kneading and the general cleanliness of the items used in processing butter. Table 2 presents the breakdown of the use of water per each stage of the processing, the fuelwood consumption along the processing stages as well as the time requirements. The study found water usage to be highest during the kneading stage. The amount of water used to wash shea kernels depends on the degree of dirt on the kernels (Table 2 and Supplementary materials Fig. 2). The average amount of water used for shea butter extraction was 305.2 ± 24.3 L. This consist of both cold water and hot water used for the washing, kneading to rinsing of crude butter for boiling. The

**Fig. 2.** Material flow analysis for shea butter production.

corresponding average amount of wastewater generated was 202.2 ± 39.5 L (66.3 %) of the total volume of water used in the kneading process. The results indicated that an enormous amount of wastewater is discarded into the environment through the shea butter extraction process (Table 9). An average of 7.6 L of water was absorbed and some were lost via the washing of the kernel to the ground. However, the water absorbed by the kernels was allowed to dry for about 2 h before crushing.

Fuelwood and time quantification at various stages of processing

The study found that the energy for processing shea butter largely came from fuelwood and electric-powered crushers. The method of combining both manual and mechanized operational processes is considered semi-mechanized. The study found that an average of 49.7 kg of fuelwood costing ₵7.40 was required to process 86.30 kg of shea kernel. The fuelwood was mainly used for roasting and heating water, and boiling extracted paste as shown in Table 3. Presented in Fig. 3, the study showed that on average 16.9 h was spent on processing shea kernel into shea butter. The was composed of 34 min (mins) for sorting, washing (15 mins), crushing (17 mins), cooling crushed kernels (26 mins), roasting (218 mins), milling (32 mins), kneading (341 mins), boiling (209 mins), and filtering (15 mins). It also took 17.28 h for solidification. The solidification time was not factored in the total working time of the entire shea butter processing as it is dependent on the weather condition.

Deforestation and loss of vegetation in northern Ghana are both major challenges to the functioning of ecosystems and with its subsequent vulnerability of man to the effects of climate change. The study revealed that all five centres use firewood as a major source of fuel for the entire SB extraction. The average amount of firewood used to process 86.30 kg of shea kernels was 49.7 kg. The women explained that the quality of the heat generated depends on the wood type. They also added that some woods burn better than others, and hence affect the duration at certain stages of the process; e.g roasting and boiling of the crude butter. However, the type of tree firewood used was not captured in the study.

It was observed that Centre B recorded the least quantity of firewood whilst Centre A recorded the highest quantity of firewood; 58.4 kg (Supplementary material Fig. 3). This may have a long-term impact on the forest if trees are fell without replacement for some decades, deforestation will emerge. It was estimated that Centre C processed about 4475 kg (50 bags) of shea kernel per month, implying 2075 kg of

firewood per month. It is alarming to see the quantity of firewood heap at processing centres if the current firewood demand is not regulated. A study by Jasaw et al. (2017) in northern Ghana; Tamale, Wa, Kpalgun and Zagua, Zowayeli and Baleufili indicated that processing shea can cause a significant change in carbon stocks, which can result in the loss of carbon sequestration ecosystem services. For greenhouse gas emissions (GHG), rural shea butter processors emitted 3.14–3.31 kg CO₂ eq/kg shea butter, while urban processors emitted slightly less (2.29–2.54 kg CO₂ eq/kg shea butter). Continuous emissions of GHG could pose debilitating impacts on the local and global climate. The study suggests an alternative energy source; natural gas. Shea butter processing accounts for high fuelwood consumption in many parts of northern Ghana. The cost of firewood varied from place-to-place ranging from GH₵4.0 – GH₵9.7 for processing a bag of shea kernels. Thus, the nature of inputs requirements and production process presents implications for conflicts over natural resource use and sustainability as more processing takes place.

Furthermore, it was observed that the type of stove used is a contributor to the amount of wood required and weather conditions (wind). Data presented revealed that production Centres A and B recorded the lowest and highest amount of wood 41.5 kg and 58.4 kg respectively (Table 3). From observation, local tripod stone stoves and improved stoves were used by the women. The local tripod stone stove was observed to yell heat away due to wind influence compared to the improved stove.

Electricity consumption data was taken for two processing centres, two used diesel machines and one not recorded. Thus, the energy analysis data was limited and the cost of crushing and milling were considered for the study instead of the consumption of energy (Table 7).

The factors that influence the processing (kneading, roasting and sorting of bad kernels) time included, the number of women per kg of the kernel and their ability. Among the processing stages, kneading was notably the most time-consuming stage in shea butter extraction. All five centres did manual kneading of the paste to crude butter. Comparing the time spent on kneading and its associated cost, the study revealed that, kneading is the second most costly stage after the cost of shea kernels (Fig. 3). The average kneading process takes 5.68 hrs out of total working hours for shea butter extraction; 15.12 hrs. This implies that 1/3 of the total processing period, is spent on kneading, thus accounting for its second most expensive category of input cost. Besides this, handcraft butter has a niche market, especially in the cosmetic industry. Hence, shea butter extraction cooperatives should be resourced adequately with modern state-of-the-art kneading equipment to reduce

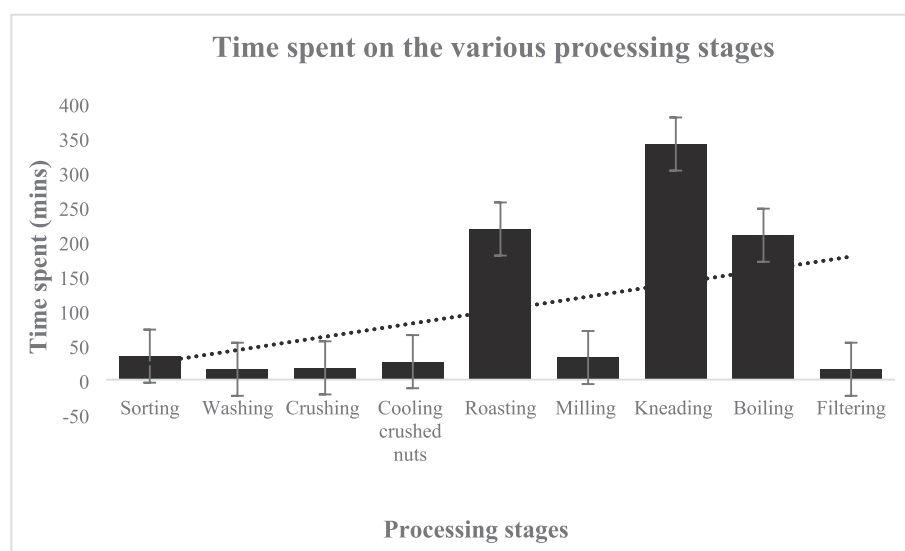


Fig. 3. Time spent at each of the processing stages.

the labourious nature of the kneading process and by extension enable them to process more shea kernel per day. It was observed that a minimum of four women is required to knead paste from 86.30 kg of kernels in two days. Less than this number according to the women would require more time and vice versa. Thus, the more hands the faster the processing and the less cumbersome it becomes on one shoulder. This is one of the main reasons why women have learnt to work in teams (cooperative centres) to unanimously achieve success.

Input and outputs analysis of shea butter processing

The cost of crushing, milling, firewood and labour from the study of the five processing centres was significantly different among the centres. The minimum processing cost was recorded by Centre E and the highest cost was recorded at Centre D (Table 4). The cost-benefit analyses as shown in Table 8 revealed a surprising fact that the women do not benefit from the shea butter business as expected to improve their financial status. The return on investment made in shea processing is an important component of the decision-making process in the shea business. From the study (Table 10), it was shown that there is virtually no profit in the shea butter business, especially in the cases of Centres A and D. The study revealed that the cost of inputs outweighed the revenue from the butter, which is vividly seen in the calculations (Table 6).

From Table 4, Centre C measured the highest weight of shea kernel, the highest amount of water used, the highest shea butter extracted, the highest wastewater generated and less time spent on the extraction process. However, though the processing facility at Centre E recorded the lowest weight of shea kernel, except for the processing Centre C, it had the highest wastewater produced after washing. Generally, the highest volume of wastewater was produced after the first rinsing of crude butter. An assessment of the output of shea effluent to shea cake formed from the extraction of a unit amount of shea kernel (Table 5) showed that centre E recorded the highest total amount of shea cake of 69 kg. The study further showed that the cost of shea kernel (86.3 kg) was the highest (GH¢108.60), and the others milling (GH¢80), kneading (GH¢20), firewood (GH¢7.38), crushing (GH¢4.20) and water (GH¢2.55) in descending order (Table 6). This reveals that profit in the shea butter production business can be maximized if the cost of the shea kernel is subsidized. As shown in Fig. 3, there was a relationship between shea butter output, wastewater, and shea cake (by-product) (Fig. 4). Economic analyses of inputs in shea butter production were established from the study as shown in Tables 6–8.

The study further estimated the amount of money required to process a unit amount of kernel to shea butter to be GH¢ 162.73 with the cost of shea kernel bearing 66.7 % of the total cost of production. The study also revealed low levels of profit or no profit upon all the time, energy and resources that women commit to processing shea kernel into butter (Table 7). From the study, the women have been making losses

Table 4
Output of shea butter and wastewater.

Processing cooperatives	Shea butter (kg)	W1 (L)	WWR1 (L)	WWR2 (L)	TVWWR (L)
A	30.0	41.3	189.8	27.3	217.1
B	28.0	37.8	126.6	13.5	140.1
C	33.0	49.5	226.0	10.5	236.5
D	30.5	48.0	130.0	58.0	188
E	26.8	80.0	196.0	34.0	230
Average	29.7 ± 2.39	51.31 ± 16.7	173.68 ± 43.6	28.66 ± 19.0	202.34 ± 39.5

*W1-volume of wastewater obtained from washing shea kernels, WWR1-wastewater obtained after first rinsing of crude butter, WWR2-wastewater after second rinsing of crude butter, TVWWR-total volume of wastewater from kneading to crude butter rinsing process.

Table 5

Outputs of shea effluent to shea cake formed from the extraction of a unit bag of shea kernel.

Processing cooperatives	Shea wastewater/effluent (L)	Dry brown cake from effluent (kg)	Dark brown cake after filtration (kg)	Total of shea cake (kg)
A	217.1	20.3	26.2	46.5
B	140.1	7.4	26.6	34.0
C	236.5	5.5	42.8	48.3
D	188.0	8	28.5	36.5
E	230.0	11	58	69
Average	202.34 ± 39.5	10.44 ± 5.9	36.42 ± 13.9	46.86 ± 13.8

unknowingly which have not been noticed due to poor evaluation of their production costs. This finding corroborates with Bulmuo (2012) in the Kassena-Nankana West District who revealed that shea butter production is not a profitable venture but a source of income to address household needs. However, in Kaleo, a study by Tweneboah Kodua et al. (2018) using a well-structured questionnaire to obtain relevant data indicated that shea butter making in the study area is profitable with positive average values of gross margins, net incomes and net returns on investments (See Table 9).

The highest profit was recorded at Centres C and E GH¢17.16 and GH¢5.63 and respectively (See Table 10) which were far less than 20 % profit (GH¢ 25.9 per 86.3.kg bag of kernels processed) i.e. considerable for business profit-making in a fair market (Corporate Finance Institute, 2021). The gross profit recorded by Centre C does not merit a day payment per woman investing her time for the three days of shea butter production. Currently, the minimum wage for the Ghanaian worker is pegged at GH¢8.8/working day and is projected to be GH¢9.68/working day in 2018 (Wage Indicator Network, 2018). This implies that, for three days of work on a unit amount of nut, a woman investing in the shea butter processing business should earn a minimum of GH¢26.4 net profit per bag (Table 6). Based on this fact, it is necessary for price review per kilo of shea butter to augment the profit levels of the shea butter business for these vulnerable women since they seem not to consider details of inputs in the cost of the butter for sale (See Table 10).

The negative environmental externalities associated with shea waste cake

The drying process and post-drying period of shea butter effluent (SBE) to cake is a major challenge at the SB production centres. Most plants cannot thrive in such areas and other living organisms around the centres. It was observed that no plants or weeds were found in areas where the waste cake was dried. In some centres where SBE is discharged into gutters creates a nuisance to surrounding inhabitants. The stench is a problem for both indigenes and women processors. Animals also sometimes become victims as they fall into the pits/dugouts (2–4 m deep) of the wastewater. A study by Adewoye et al. (2013) evaluated the effects of SBE on the freshwater inhabitant using *Clarias gariepinus* as a biological model. The study showed that the effluent could cause erratic movement, air gulping, loss of reflex, moulting, barbell deformation, haemorrhage, and excessive mucus secretion in fish exposed to a higher concentration of shea butter effluent when they are disposed or deposited into surface water resources. Therefore, indiscriminate discharge of shea butter effluent into the environment and for that matter water bodies could be detrimental and should be vehemently discouraged. This suggests that shea effluent needs to be managed properly. Treatment methods could be explored to conform to international standards before discharge into gutters, rivers or streams. Also, closing the loop with cleaner production methods by exploring the beneficial use of the shea cake for fertilizer production could be helpful.

Table 6

Cost of shea butter processing at various stages.

Processing centre	PSB	CFW	CW	CC	CM	CK	TCP (GH¢)	TCP (\$)
A	120.00	9.70	2.29	1.50	4.00	12.00	149.49	24.50
B	108.00	5.50	2.52	2.50	5.00	24.00	147.52	24.18
C	115.00	9.70	2.79	3.00	7.00	12.00	149.49	24.50
D	100.00	8.00	2.45	7.00	15.00	45.00	177.45	29.08
E	100.00	4.00	2.71	7.00	9.00	7.00	129.71	21.26
Average	108.60	7.38	2.55	4.20	8.00	20.00	150.73	123.52

*PSN = price per bag of shea kernel, CFW = cost of firewood, CW = cost of water, CC = cost of crushing kernels, CM = cost of milling to paste, CK = cost of labour for kneading, TCP = total cost of production. All units in Ghana cedis (GH¢). The profit expected was calculated using 20 % of the cost of processing. Exchange rate of 4.83 (Focus Economics, 2019).

Table 7

Process analysis (economically).

Input	Cost (GH¢)	% of Total cost of processing
Shea kernel	108.00	66.7
Fuelwood	7.38	4.5
Water	2.55	1.6
Crushing	4.20	2.6
Milling	8.00	4.9
Transportation	12.00	7.4
Labour expenses	20.00	12.3
Total	162.73	100

Table 8

Shea butter process inputs and quantities.

Input	Quantity
Shea kernel	86.3 ± 1.9 kg
Firewood	49.6 ± 7.2 kg
Water	305 ± 24.3 L
Cost of production/labour	GH¢150.73 ± 8.0
Labour (No. of women)	4–8 persons
Time	16.35 h

Conclusion

In Ghana, shea butter production is dominated by women in the industry who mainly uses manual and semi-mechanized methods. Contemporary techniques and equipment for shea kernel processing into

butter require the use of inputs which includes mainly shea kernels, water, labour and time. This study focused on the input–output relationship and profits maximization using material flow analysis as cross-sectional data from five shea butter extraction women cooperatives processing centres located in the Northern and Upper West Regions of Ghana. The study showed that the cost of shea kernel was a major factor in profit maximization in the shea butter production industry. Incorporating sustainable value addition promotion in the shea butter industry can guarantee secured income and increase women's resilience against social, economic and climate uncertainties as this would cater for the profit aspect of the women in the industry. Long periods spent in the kneading process which prolongs the entire shea butter production time could be curtailed by the use of modern machinery. Enormous quantities of wastewater are deposited into the environment via shea butter production without careful environmental management of the wastewater. It is recommended that:

- Comprehensive analysis of the chemical compositions of the waste (wastewater and cake) may be required to explore the possible benefits of the reuse of the effluent.

Table 9

Shea process output and quantities.

Output	Quantity
Shea butter	29.7 ± 2.4 kg
Wastewater	202.3 ± 39.5 L
Shea waste cake	46.9 ± 13.8 kg

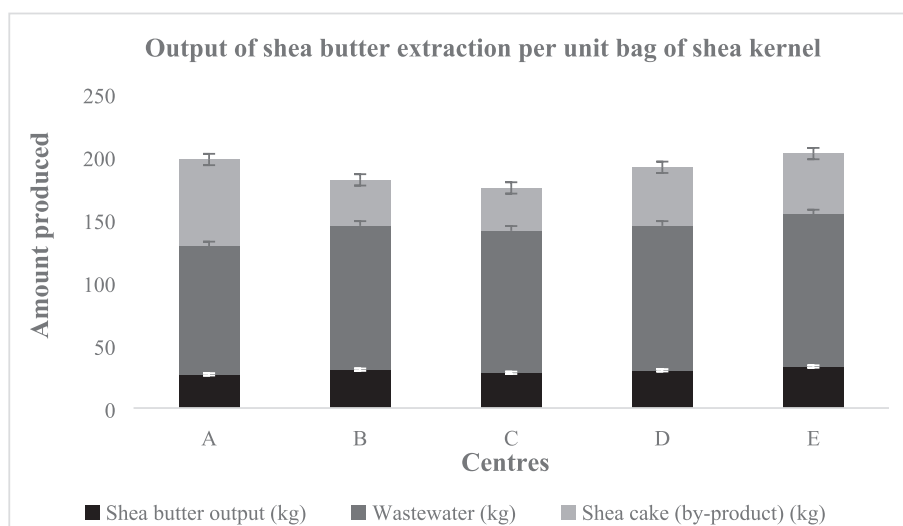
**Fig. 4.** Summary of the output of shea butter extraction per unit bag of shea kernel.

Table 10

Cost of production and cost-benefit analyses on the unit bag of shea kernel to butter.

Processing centre	TCP (GH¢)	TSSB/bag (Gross revenue) (GH¢)	Gross profit (GH¢)	Expected profit at 20 % TCP (GH ¢)	Expected profit at 30 % TCP (GH ¢)
A	149.49	151.5	2.01	29.898	44.847
B	147.52	141.4	-6.12	29.504	44.256
C	149.49	166.65	17.16	29.898	44.847
D	177.45	154.03	-23.42	35.49	53.235
E	129.71	135.34	5.63	25.942	38.913
Average	150.73	149.78	-0.95	30.146	45.219

* TCP = total cost of production, TSSB = total sale of shea butter. NB: Gross profit was calculated as follows: Total sales – total cost of production. Percentage profit calculation = % x TCP; %–20 % or 30 %.

- To enhance the quality and to fast-track shea butter production, the government and NGOs can make available modern machinery to be used in the production of shea butter.
- Various stakeholders and buyers can amend their policies to manage the price of shea butter to enable the women to actually make more profit from the shea butter should
- The study did not cover the loss of other tree benefits for firewood in the shea butter production as it wasn't part of the study focus. However, it's an area we recommend for future studies.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

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