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Article

Shea (*Vitellaria paradoxa*) Butter Production and Resource Use by Urban and Rural Processors in Northern Ghana

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Abstract: This article explores the use of field experimentation in presenting an account of input inventory, material quantities, and the process flow for shea butter production in Ghana. The shea fruit is a non-timber forest product (NTFP) that is indigenous to ecosystems in semi-arid regions of Africa. Current methods and equipment for processing shea kernel into butter impose a dilemma of excessive harvesting of fuel wood for heating and the use of large quantities of water. Thus, the nature of input requirement and production process presents implications for conflict over natural resource use and for sustainability as more processing takes place. Material flow analysis was applied to the data generated from the processing experiments. The outcome was discussed in focus group discussion sessions and individual interviews as a way of data triangulation to validate study parameters. Results from this experiment showed that the quantity of water used in urban processing sites was higher than that used in rural sites. On the other hand, fuel wood use and labor expended were found to be higher in rural sites per unit processing cycle. The nature of the processing equipment, accessibility to input resources, and target market for shea butter were key determinants of the varying resource quantities used in the production process.

Keywords: shea butter; resource use; material flow analysis; field experimentation; urban processors; rural processors; material quantities; fuel wood; water; labor; Ghana

1. Introduction

Shea (*Vitellaria paradoxa*) is a key non-timber forest product (NTFP) occurring largely in off-reserve forests in many parts of Africa, including northern Ghana. Harvesting non-timber forest products (NTFPs) has been promoted worldwide as an opportunity to both enhance local livelihood and contribute to environmental sustainability through biodiversity conservation [1–3]. The non-wood/timber forest species is emphasized here in preference to tree logging and other timber-based harvesting. In many developing countries, NTFPs, such as mushrooms, medicinal plants, wild fruits, honey, and insects, remain the basis for socio-economic sustenance [4]. However, the effectiveness of NTFPs and their related goods and services toward achieving sustainable development has been questioned by some development experts as being slow and difficult to measure [5]. More recent reports show that the value and contribution of NTFPs to livelihood and sustainable development is unclear, largely because of an underestimation of their products and services [6]. It is clear that if more efficient and sustainable value addition can be achieved for shea, a major NTFP for rural households in northern parts of Ghana, many would be able to secure an income beyond the basic means of survival and build resilience to increasing climate and ecosystem changes. To derive maximum utility from shea, the kernel from the fruits are usually processed into butter for value addition using water, fuel wood, and labor as critical inputs. Because extreme climate change events such as droughts and floods continue to occur, many local experts continue to cite excessive tree cutting for fuel wood as one of the contributory factors to the changing climate and ecosystem events, particularly in the drier savanna regions of Ghana [7]. The exact quantities of fuel wood used in the area for processing shea and the accompanying loss of tree species and other vegetation cover have not been investigated.

This article aims to apply the concept of material flow analysis (MFA) as the main analytical tool for understanding the processes that the shea kernel undergoes for value addition and transformation into the more usable shea butter; we also aimed to determine the accompanying quantities of input–output material involved. The specific objectives were (I) to conduct an input–output inventory and to measure the material quantities involved for each shea butter processing stage in the cycle and (II) to estimate the resource use and performance of key inputs such as fuel wood, water, and labor for urban and rural processing systems on 1 kg functional unit of shea butter output. The study measured resource quantities through field experiments, discussed process flow in focus group discussions (FGDs) and individual interviews in rural and urban settings.

2. Literature Review

Shea (*V. paradoxa*) is an agro-managed tree crop, which is found in the wild, growing in parklands in large parts of Sub-Saharan Africa and savannah ecosystems of northern Ghana [8]. Typically, the shea occurrence zone lies in a region of 600–1400 mm of annual rainfall [9]. Shea provides fruits for direct consumption, providing good quality vitamins and energy to rural dwellers. The shea seeds/kernels (nuts) from these fruits are sold raw as kernels or further processed into shea butter for cooking, skincare, medicine, and other benefits in many areas of human well-being and rural development [8]. The trees provide regulation through carbon sequestration, wind breaks, and preventing erosion in addition to serving as a habitat for other organisms and direct provisioning of fruits. The fruits of shea are usually processed into butter and many other products. Almost every part of the shea tree is used, for example, the fruit is eaten and the leaves are used as fodder for animals and a good alkaline for the paint industry [10]. In Ghana, shea trees grow in abundance in the wild in almost half of the country, occurring in almost the entire area of northern Ghana with a land coverage of over 77,670 km^2 [11]. It is estimated that approximately 9.4 million shea trees grow in Ghana [12].

A shea processing factory was recently established in Buipe in the northern region; this contributed to a reduction in the total exported quantity of raw kernel. The export of raw unprocessed kernel is still significant for many actors along the supply chain; however, export of the raw beans usually yield very low - dividends to the pickers at the community level, who usually are not equipped with the supporting infrastructure and machinery to process into butter and effectively be a part of the more profitable end of the supply chain. With the recent production levels, butter extraction for export has been increasing steadily while raw kernel has been fluctuating according to the Ghana export promotion authority. Since becoming a substitute for cocoa butter extract in the cosmetic industry, shea butter export has been increasing in recent years (Figure 1). It is estimated that shea can potentially yield up to 150 million US Dollars and contribute up to 12% of the total household income in the poorest households of the savannah areas [13]. Shea is exported as raw kernels or as shea butter to serve the high-value cosmetic industry and the wide range of food products, including chocolate in the United Kingdom, Germany, the Netherlands, and Japan [8,11,12,14]. The reviewed literature on shea reveals at least three broad categorizations. The first body of literature is centered on the agronomy of the plant and the spatial spread as well as the estimated yields [15,16]. They show that shea is not planted or cultivated as with other agro-crops but occurs naturally in the wild with adaptations to survive bushfire and other harsh conditions. The shea occurring in the wild could take up to a decade to mature into fruit bearing trees. They are usually maintained and managed on farmed parklands till maturity. On uncultivated reserves, shea trees in particular are consciously not cut down for fuel wood.

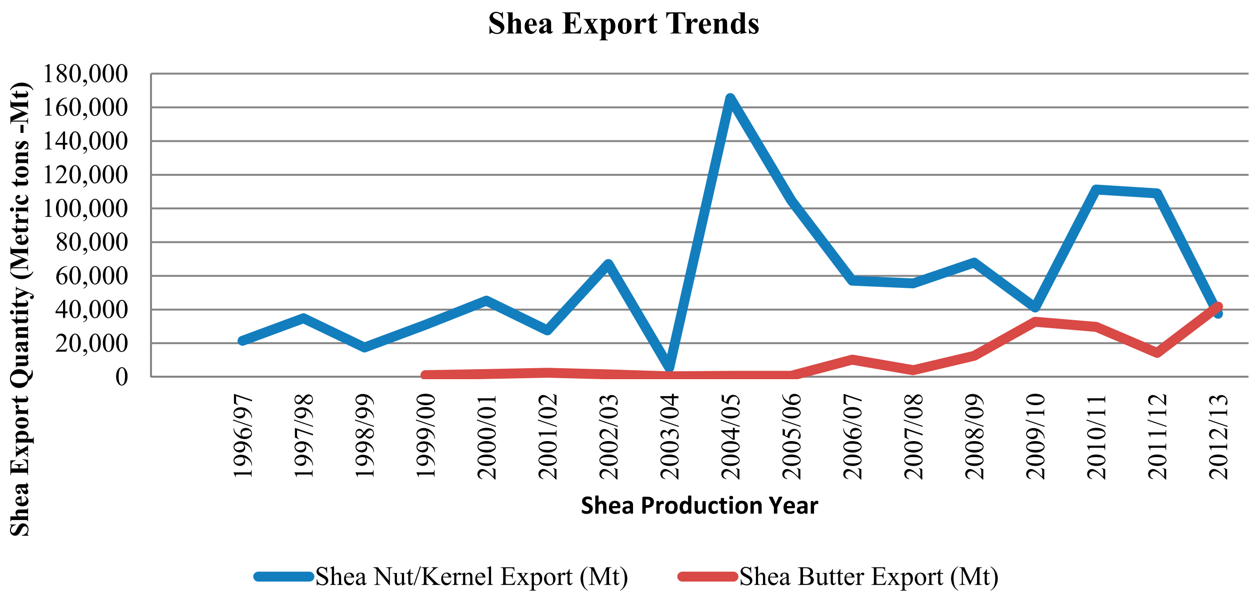

Figure 1. Shea production and export trends (Ghana Export Promotion Authority (GEPA) 2014 [17]).

The second body of literature is rooted in reports of development organizations such as the United Nations Development Programme (UNDP), Japan International Cooperation Agency (JICA), United States Agency for International Development (USAID) and other organizations. They largely concentrate on the potentials of shea butter production and the quality of the kernel and butter in reports and training manuals for supporting their capacity building programs that help processors improve shea butter quality as well as generate employment and the associated livelihood outcomes for rural stakeholders [12,18,19]. Other literature in this category takes on the gendered nature of shea with women as the major actors in the local processing [13,14,18,20,21]. The third body of literature analyzes the economics of input– output relationships for different local processing methods such as the traditional, semi-mechanized and other improved processing techniques. [22] The choice of shea processing technique or method has implications for technical and allocative efficiency of input resource use. Aspects such as accessibility to resources, related output levels, environmental effect as well as processor's capacity to operationalize efficient schemes, and market type were not covered in the literature reviewed. Other studies by Glew and Lovett [23] considered the low carbon potential for using different stoves for shea butter processing with life cycle analysis (LCA) to estimate carbon footprint and the associated greenhouse gas emissions associated with the production of shea butter in line with British standards. The authors argue that the use of shea butter in high-value cosmetics and the food industry presents opportunities for low carbon emission. The study argues that there is a critical need to evaluate the full production chain and the associated resource uses in different scenarios such as different processing techniques. For instance, the availability and use of simple machinery such as crusher, milling machine and roaster stove becomes a critical factor in accurately estimating the environmental load of shea processing. This provides an important justification for our study on resource use and the consequences for declining natural capital in the area. At present, village residents cover increasing distances to access fuel wood, some have resorted to cutting the shea tree and similarly preserved tree species for fuel [24]. Consequently, general accessibility to ecosystem-based services including provisioning service such as fuel wood fort households in northern Ghana has become difficult with increasing degradation of the environment [25]. It has become imperative to examine the propositions that scientists advance for the sustainability of forest natural resource use.

3. Materials and Methods

The methodological approach in this study was designed to offer interdisciplinary insights by applying a mixed method of scientific field experimentation, focus group discussions (FGDs), and individual interviews on shea butter production and resource use. The data and views obtained from these three sources enabled triangulation for a better reliability of the exact parameters and quantities involved in the study [26]. Many other studies have relied on questionnaire surveys for analyzing the processing of shea butter and the links to rural livelihood [14,20–22,27]. Some studies conducted by Stichting Nederlandse Vrijwilligers (SNV)—Netherlands Development Organization [18] on energy use analysis for promoting the use of a roaster stove in shea butter processors provided a useful basis for designing this study. In this study, primary data was collected from three main sources; field experimentation was conducted in which the researcher participated in the shea butter making process, inventoried all inputs, and physically measured the mass of fuel wood, the volume of water, and the labor in man-hours at each stage of the processing of a unit quantity of shea kernel into butter in rural and urban locations across two administrative regions in Ghana (northern and upper west regions); FGDs were also conducted separately with a control group of at least a dozen women in each study site who did not participate in the particular experiment but are shea butter processors. The information generated in FGDs facilitated the explanation of the process and choice of materials as well as verified and validated the findings generated from the experimentation process. Finally, separate one-on-one individual interviews were held for at least one processor with more than 10 years' experience in shea butter processing. The processor was purposively selected in each study site who did not participate in the experiment. The views and explanations provided by the three sets of data sources enabled triangulation of the views and explanations with the empirical findings. Thus, triangulation of data sources allowed for better reliability of the findings [26].

3.1. MFA and Shea Production Process

MFA is one of the many tools used to give expression to life cycle thinking (LCT) around sustainable development [28,29]. The term MFA may also refer to a family of tools, which includes a wide variety of analytical approaches and measurements, ranging in scope from economy-wide to substance- or product-specific analyses [30]. MFA has been widely used in industrial ecology as the main analytical tool for substance flow accounting in industrial set-ups and is now growing to many more sectors. Studies on MFA have been proposed to be useful for environmental management in many regions as a necessary pre-requisite for operationalizing the concept of sustainability and for supporting the effective planning and management of natural resources [31,32].

Recent MFA studies show good analytical potential for enhancing the understanding of the flow structure and processes in both agricultural commodities and NTFPs as they undergo transformations in the context of sustainable development [33]. MFA allows for adoption of non-forest agricultural production systems. It requires a clear definition of the objectives, identification of inputs, definition of the process flow, and determination of implications for a system balance. Analyzing material flow in the society can be done using various system boundaries and choices of materials [31,34–38]. MFA aids in characteristically mapping the physical flow of natural resources and materials into, through stages, and out of the economy [30]. In this article, we apply the MFA process to shea butter production; an initial step is the input inventory of direct material inputs (DMI) for producing shea butter and describes the flow of materials within the system to generate direct outputs (DOs) of shea butter and shea waste. The flow relationships and steps are then mapped and connected to the output (Figure 2).

The system boundary can either be geographical, which is often used to analyze questions about the material flow in a given area such as a municipality, region, or country, or the limits within which the material flow is organized [37]. For instance, many studies, including van der Voet's, set a system boundary, which comprised limits around the following three steps: goal and scope definition; inventory and/or modeling; and finally interpretation [39,40]. In this study, the MFA framework was applied in a value addition process for a non-timber forest product, the shea. Locating the study in urban and rural settings adds an innovative dimension to the analysis. The conceptual foundation for this study is the need to widen the understanding of the timber resources, labor, and water that are often expended when NTFPs are processed. The physical flow of materials as well as the quantities involved in space and time were measured and analyzed for performance in both rural and urban locations. This considered their differentiated capacity expressed in the type of production equipment used, quantities involved, and target market linkages for finished shea butter in operation. The underlying goal remains the same: to increase the knowledge and develop strategies to integrate concerns of the environment and sustainable development in human activities [41].

This article provides a systematic view on the association between processes and their performance in using natural environmental resources on producing shea butter service units in rural and urban settings. The system boundary therefore focuses on raw shea kernel beans as the preliminary raw material through all stages of processing to obtain shea butter (Figure 2). The direct inputs are water, fuel wood, and labor (major input variables in a typical shea butter processing system). The functional unit used to provide a reference for the performance of the inputs and outputs is 1 kg of shea butter. Indirect inputs, such as oxygen and the chemical and biological processes, were considered to be beyond the limits set for this study and outside the system boundary. We also recognized that shea butter, as produced by the system defined herein, undergo further refinement processes and additional processing within different stages along the material flow system which were treated beyond the boundary set for the present study (Figure 2).

The crude butter is consumed directly in households and agro processing industries or exported in the raw state for use in other industries. Waste residue is generated, part of which is dried and reused as an energy input to the system in subsequent processing cycles. The liquid wastewater is discharged into the ground and subsequently treated. This article recognized that the ecosystem's organization of the flow of material, energy, and information can serve as a useful model for how industries could be remodeled to reduce pressure on ecosystem services, inflow of raw materials, and absorption of outflow from industry and society as a contribution to sustainability.

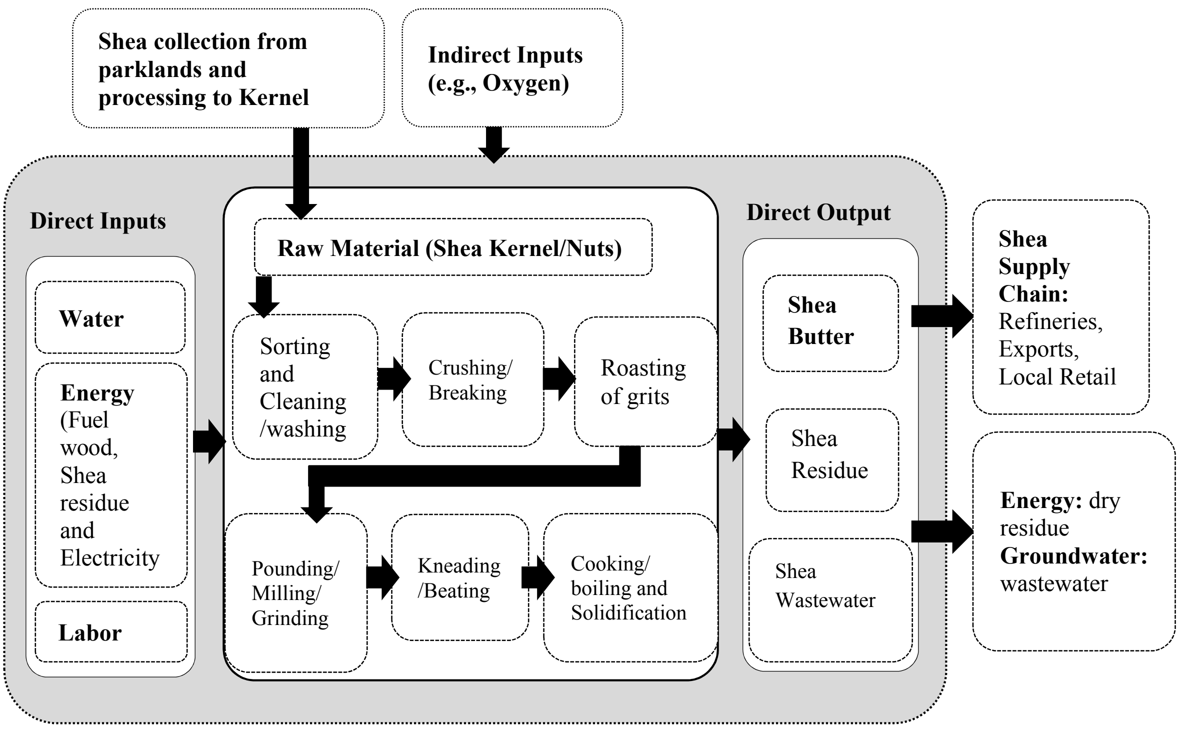

Figure 2. Material flow analysis for shea butter production. Grey area = system boundary.

3.2. Study Sites

The study sites were selected in three parts. The first grouping of study sites is the northern and upper west regions, which are mainly savannah grassland in the North and in the northwest of Ghana. The area was selected on the basis of predominance of the shea tree [10,14,15], and the level of processing recorded in official statistics from the Ghana Export Promotion Authority (GEPA). Tamale and Wa are the capital cities for the northern and upper west regions, respectively, and were considered as the urban locations for this study. Within these urban centers, two locations from each area were selected in which the experiment was to be conducted. The main consideration for the selection of location was the relevance of the areas for shea kernel processing as an activity for livelihood and the willingness of the processors to take part in the research experiment. It is very common to see women in groups processing shea kernel into butter in these locations [13,14,21,27,42].

The final part was the selection of two rural communities in one administrative district in each region. By selecting urban and rural locations with their unique social, economic, and environmental characteristics and endowments, the study was able to establish variations in shea material flow structure, relative material, and input/output quantities for the different rural and urban locations. In selecting rural communities as case sites, we focused on communities in which the activities of the project on Enhancing Resilience to Climate and Ecosystem Changes in Semi-Arid Africa (CECAR-AFRICA) were ongoing in the northern and upper west regions of Ghana. Zagua and Kpalgun of the Tolon district of the northern region and Zowayeli and Baleufili in the Wa West district of the upper west region were selected for this study (Figure 3). Even though no official information on the number of processing centers in the study area is available, we can normally find at least one processing center in each section in urban Wa and Tamale. In the rural locations, two processing sites were found in each of the sites except Kpalgun which had at least, four groups on that site.

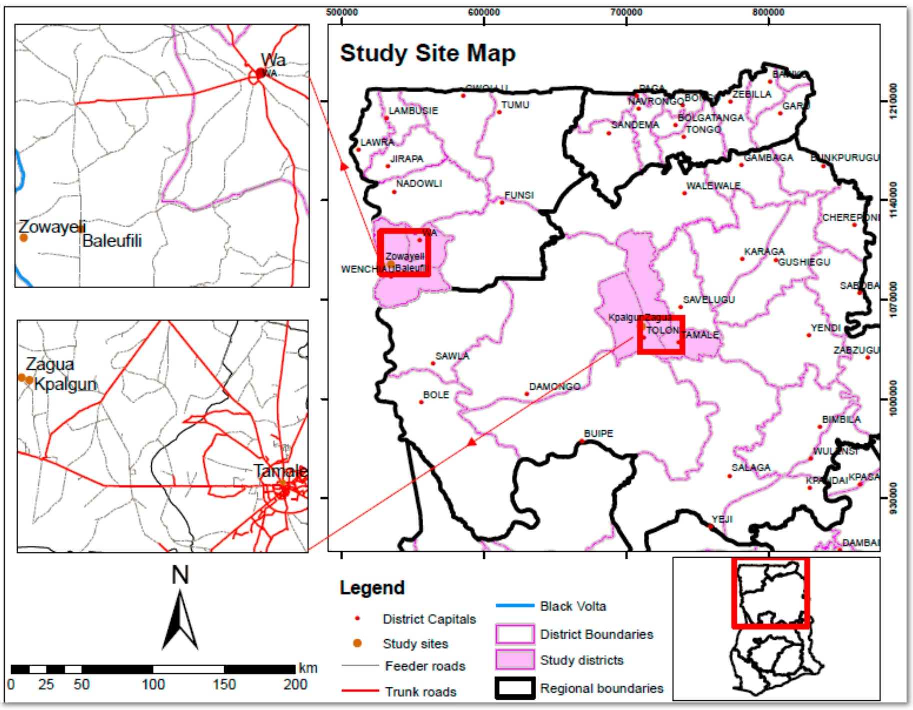

Figure 3. Map showing study locations.

The study area falls within the Guinea savannah agro-ecological zone with two distinct seasons per year: a rainy season usually lasting from the month of April to October and a dry season for the rest of the year. Rainfall and temperature are highly variable. In particular, rainfall distribution is normally irregular, intermittent, and torrential [43]. Average annual rainfall ranges between 900 mm and 1000 mm. The rainy season usually starts from April and can reach a maximum in August/September. Rainfall declines by the end of October followed by the long dry season, which sets in by late March/April, and recently some communities received their first rains only in June [7]. The highest temperatures are normally recorded in March and can rise as high as 45 °C during the day. Small-scale food crop production and keeping of livestock are the predominant livelihood activities in the area [7].

3.3. Procedure for Experiment (Production Process)

The field experiments were conducted in February–March 2014 and July–September 2014 during the off season and on season for shea fruits in the area, respectively. At each site, the researchers were permitted to observe, take measurements, and obtain explanations to some activities as the processing team performed their activities. It took an average of four days to complete the processing at each site.

Sorting and cleaning: Bags of kernel—128 kg and 87 kg—were emptied onto clean platforms in locations in the northern region and the upper west, respectively. Chaff, stones, and deformed or discolored nuts were removed. The nuts were washed in cold water. The dirty (used) water was poured away and the washed kernel nuts were dried in the shade and the time was recorded. The kernels were weighed again; the 87 kg-bag lost approximately 1 kg, and the 128 kg-bag lost approximately 2 kg.

Crushing: The shade-dried kernel was crushed into smaller grits. In all rural locations, pounding of the nuts was done using a mortar and pestle. In the urban locations, the kernel was carried in large basins to an electric powered nut crusher that crushed the nuts into grits. The electricity consumed was estimated by taking electric meter readings. The time spent for pounding in the rural areas was also recorded.

Roasting: A roaster stove (improved, specially constructed metal frying chamber on a fuel wood efficient stove) was used to fry kernel grits in the urban locations in Tamale, northern region, while an iron pot or large frying pan on three stone stoves was used in the rural processing sites and all sites in the upper west region. The three stone local stoves are very popular in these areas. It is normally three stones on which the cooking pot is suspended, while the fuel wood is placed underneath. The excessive heat generated is dissipated as a waste product in open air.

Milling/Grinding into paste: An electricity powered milling machine milled the roasted kernel grits into paste at urban sites in Tamale and Wa. The electric power consumed was again measured and recorded. In the rural locations, the roasted grits were first pounded to obtain a rough paste, which was subsequently placed on a grinding stone in bits and manually ground to obtain a smooth paste.

Kneading/Beating: The milled shea paste was cooled and distributed into basins in several batches where water was continuously added with continuous stirring and beating by hand. Warm water was later added when the brown paste began to change into a whitish emulsion. Fuel wood and dry kernel residue provided heat, and their quantities were accordingly measured and recorded. The volume of water used and time spent were also measured and recorded. The whitish emulsion solidified and was later transferred into another basin, while the wastewater level was measured and poured away.

Heating: The resulting emulsion was heated in large aluminum pots to extract the oil. As the heating started, a long wooden stirrer was used to stir continuously until all of the emulsion turned into liquid oil. The stirring was discontinued, while the boiling continued for some time until all the water evaporated. Some solid impurities that floated to the top were continuously removed. The three stone stoves were used in all eight locations, and it was at this stage that the most fuel wood was burnt (Table 2).

Filtration and solidification/cooling: A cloth was used to sieve the boiled liquid oil into an empty pan; the cloth filtered out all impurities. The liquid oil was left overnight to cool and solidify into shea butter. The weight of the shea butter was measured and recorded for each location; however, the cooling time was estimated to be 12 h for all sites because of an overnight time span in all the sites.

Packaging: In the urban and rural locations in the upper west, the butter was molded into small bits of round balls of approximately 18 g each. These were placed into a separate basin half filled with cold water. In the rural northern region, the shea butter was heaped onto a basin to assume a conical shape and covered with a wet cloth in readiness for retail. In urban Tamale locations, the butter was packaged in carton boxes with transparent polythene lining, weighed, and stored in readiness for sale to cosmetic industries within Ghana or to exporters.

Storage: In all four rural sites, there was no designated building or factory for conducting the shea butter processing activities. They generally utilized the shade provided by trees for working. The kernel raw materials, which they bought from collectors or from nearby markets, were usually stored at convenient spots in the compound of their houses or homes protected from direct scorching sun and rain. The shea butter produced is also usually stored in the living rooms of the processors ready to be marketed. The case is slightly different in the urban sites because they have dedicated infrastructure for shea processing with sheds that provide shade for processors and separate storage rooms for kernel raw materials and the processed shea butter. The processing sites are referred to as shea processing centers in the urban areas.

Equipment used to conduct the experiment included a platform scale measure for taking the mass of kernel, fuel wood, and butter; a tape measure for measuring wood length and dimensions; a calibrated container for measuring water volume; a stopwatch for keeping time used in each stage of the process, a thermometer for measuring the temperature of heating; and a tabletop scale for measuring the mass of shea butter produced.

The raw material was the shea kernel. Kernels in the upper west were held in jute sacks that weighed 87 kg. After taking off the chaff and spoilt kernels, the raw kernel weighed approximately 86 kg in all four sites. In the northern region, the kernel is commonly held in large fertilizer sacks weighing 128 kg. Chaff and spoilt nuts were taken out again. The resulting raw kernel weighed approximately 126 kg in all four sites in that region.

Participants in the experiments were groups of women, who have been working together sampled in all case study locations because they are the predominant gender engaged in shea processing [13,14,20,21]. The women have traditionally been engaged in shea butter processing as it is one of the major local economic activities undertaken by women in the savannah areas of Ghana. They worked as a team at each experiment site (four rural and four urban) in the northern and upper west regions of Ghana (Table 1).

Table 1. Distribution of processing equipment and parameters found in the experiment sites.

Region	**Northern Region**				**Upper West Region**			
Setting	**Rural**		**Urban**		**Rural**		**Urban**	
Experiment site	Kpalgun	Zagua	Tamale-Tiyumba	Tamale-Tiehisuma	Baleufili	Zowayeli	Wa-Kpaguri	Wa-Mangu
Equipment used at least a big bowl (basin) and a bucket were used in all processing stages at all locations								
Crushing/Breaking of nuts stage								
Mortar and pestle	✓	✓			✓	✓		✓
Electric Crusher			✓	✓			✓	
Roasting of grits stage								
Roaster stove			✓	✓				
Frying pan	✓	✓					✓	✓
Cooking pot					✓	✓		
Three stone stove	✓	✓			✓	✓	✓	✓
Milling of grits stage								
Milling stone	✓	✓			✓	✓		
Milling Machine			✓	✓			✓	✓
Cooking/heating of crude butter stage								
Three stone open stove	✓	✓	✓	✓	✓	✓	✓	✓
Wooden stirrer	✓	✓	✓	✓	✓	✓	✓	✓
Number of participants	4 adults	4 adults	4 adults	5 adults	3 adults	3 adults	4 adults	4 adults
Gender	Females	Females	Females	Females	Females	Females	Females	Females
Processing techniques	Non mechanized	Non mechanized	Partly mechanized	Partly mechanized	Non mechanized	Non mechanized	Partly mechanized	Partly mechanized
Target market	Community and nearby retail market	Community and nearby retail market	Export and Cosmetic industry	Export and Cosmetic industry	Community and nearby retail market	Community and nearby retail market	Urban retail market and bulkers	Urban retail market and bulkers

4. Results and Discussion

4.1. Shea Butter Processing Conditions in the Experiment Sites

Table 1 shows the distribution of equipment used in the shea butter processing across all eight experiment sites organized according to the butter processing stages. The rural areas show an equipment profile characterized by high-labor demand, higher use of resources, and drudgery in their operation compared with the urban processing sites. Locations with modernized and improved equipment or machinery for various stages of processing operation are shown to be the urban sites. In addition, operations that are still manually executed are shown by processing stage and experimental site. All participants in the experiment were adult females with no formal education. The principal material inputs, which are also defined in the system boundary for the material flow analysis framework applied in this study, are fuel wood (energy), water, and labor. Liquid wastewater and quantities of solid waste residue were also measured. The processing considered in this study starts with of the raw shea kernel undergoing transformation into shea butter. In the rural locations of Zagua and Kpalgun in the northern region and in Zowayeli and Baleufili of the upper west region, we found that processors had no machinery and manually executed all operations from pounding the kernel nuts into grits through various activities to the final production of butter.

In the urban locations (Wa and Tamale towns), some of the processing stages were mechanized albeit differentiated. In three out of the four urban sites (Kpaguri, Tiehisuma and Tiyumba), the kernel nuts were crushed into grits using electric powered nut crushers. In the other urban sites (Mangu), crushing of the kernel was physically done using mortar and pestle. Again in Wa town, the three stone open stove was used to fry the grits where as a mechanized roaster stove was used in Tiehisuma and Tiyumba sites in Tamale town. The grits were milled into paste using electricity powered grinding mill in all urban processing sites. The literature on Shea treats cases according to which aspect of the processing uses semi mechanized machinery [20,22].

4.2. Input inventory and Material Quantity Accounting

The input inventory for the main resources—water, energy and labor—was organized according to each processing stage and the disaggregated quantity used at rural and urban processing sites in the northern and upper west regions for the said processing levels (Table 2).

Table 2. Direct material input and output quantity distributions by location.

Region		**Northern Region**				**Upper West Region**			
Setting Experiment site		**Rural**		**Urban**		**Rural**		**Urban**	
		Kpalgun	**Zagua**	**Tamale-Tiyumba**	**Tamale-Tiehisuma**	**Baleufili**	**Zowayeli**	**Wa-Kpaguri**	**Wa-Mangu**
Stages/Direct Material Inputs									
01	**Sorting and Cleaning**								
	Water (L)			50	55	25		40	40
	Labor (man-hours)	02:00	01:40	01:20	01:00	01:12	01:18	01:13	01:10
	Shade-Drying (man-hours)			03:00	02:50	02:15		02:20	02:17
02	**Crushing/Breaking**								
	Labor in man-hours	03:00	02:52	00:34	00:32	01:52	02:00	00:24	01:58
03	**Roasting**								
	Fuel wood (kg)	23.00	25.00	15.00	14.60	21.00	20.00	18.00	17.50
	Dry kernel waste (kg)	1.50	1.8	3.0	4.0	2.2	1.5	3.0	4.0
	Labor (man-hours)	02:12	02:05	01:34	01:30	01:50	01:56	01:34	01:43

Table 2. *Cont.*

Region		Northern Region				Upper West Region			
Setting Experiment site		Rural		Urban		Rural		Urban	
		Kpalgun	Zagua	Tamale-Tiyumba	Tamale-Tiehisuma	Baleufili	Zowayeli	Wa-Kpaguri	Wa-Mangu
04	**Pounding and Milling/Grinding grits into paste**								
	Labor using grinding stone (man-hours)	03:35	03:34			03:00	02:48		
	Labor using milling machine			00:32	00:31			00:27	00:30
05	**Kneading/Beating**								
	Water (L)	142	145	150	165	115	110	125	122
	Labor (man-hours)	02:25	02:30	02:20	02:23	02:00	02:05	01:50	01:58
	Fuel wood to heat water (kg)	3.0	3.2	2.8	2.8	2.0	2.2	2.5	2.2
06	**Boiling/Cooking of emulsion**								
	Fuel wood (kg)	36.0	35.0	37.0	32.0	30.0	29.0	27.0	25.0
	Dry kernel waste (kg)	3.0	3.4	5.5	6.0	2.2	1.5	2.5	3.0
	Labor (man-hours)	02:00	02:10	01:40	01:52	01:30	01:22	01:25	01:20
	Cooling overnight (man-hours)	12:00	12:00	12:00	12:00	12:00	12:00	12:00	12:00
	Water at packaging (L)	22	20	12	16	17	10	13	15
07	**Direct Material Output**								
	Shea butter output (kg)	34.0	33.0	38.0	40.0	29.0	28.0	31.0	32.0
	Wastewater (L)	114	102	180	187	125	92	138	125
	Solid residue (kg)	8.0	8.0	5.0	5.0	10.0	10.0	6.0	6.0

In terms of the nature of raw materials and inputs, there was no observed difference in both rural and urban locations as well as across the two regions (Table 2). The input material quantities, as measured in the experiment, varied with the rural or urban location and the processing technique and type of equipment used for specific operations. For instance, the three stone stove heath used for roasting in rural sites consumed as much as 25 kg of fuel wood per bag of shea compared with just 15 kg of fuel wood used in urban centers where the more improved mechanized roaster stoves were used. Similarly, 32 min was used in urban locations to crush one bag shea kernel into grits using the electric crushing machine, consuming approximately 1.4 kWh of electricity; however, in the rural sites, approximately 3 man-hours was spent for crushing the same quantity of kernel using a mortar and pestle (Kpalgun in Table 2).

More water was used in urban locations per unit quantity of raw material compared with the rural areas. A lot more fuel wood was used in the rural locations than in the urban locations (Table 2). The energy uses in these rural locations are characterized by inefficient systems. For instance, the three stone open stoves consumed more fuel wood compared with that of the roaster stove that was used in urban Tamale.

A lot more man-hours were used in the rural areas per unit bag of kernel to butter than those in the urban areas. Participants in FGDs explained that the no mechanized nature of the processing equipment and methods with the accompanied drudgery from manual operations accounted for the higher man-hours expended in processing shea butter in rural centers compared with those of the urban centers where operations such as crushing of kernel, milling, and roasting of grits are all mechanized.

4.2.1. Sorting and Cleaning

Except Baleufili which has easy access to water from a community dam, none of the rural locations washed the raw shea kernel before crushing (Table 2). The participants explained in FGDs that water was a very scarce input and therefore processors usually did not see the need to "waste" it by washing the kernel because they usually sort out all chaff and foreign material. However, they admitted that by not washing, the shea butter will have a lower quality appearance and attract lower prices. In all the urban locations, there was consensus that washing improves the appearance, and thereby, the quality of the butter, which enhances its attractiveness in the market. Thus, they valued washing as a very important activity in the processing chain. Their counterparts in the rural locations face challenges with regard to water accessibility; therefore, they prefer to economize its use in what they describe as "essential activities".

4.2.2. Crushing/Breaking of Raw Kernel

The crushing of the raw kernel beans is performed to obtain small sized grits for effective roasting. This activity was found to be highly labor intensive. Four women, pounding in turns, took an average of 3 h to pound approximately 126 kg of kernel in the northern region and an average of 2 h to pound 86 kg of kernel in the upper west locations. The more elderly women processors dread this activity as it requires considerable physical strength.

4.2.3. Roasting of Raw Kernel Grits

Roasting of the kernel grits is performed to facilitate easy oil extraction. The grits are usually subjected to very high-heating temperatures, while being continuously stirred until a uniform brown color is obtained. A considerable amount of care is taken to avoid burning of the grits. Once burnt, the butter quality is compromised and may be difficult to sell. At the locations in Tamale, they used a relatively improved, more efficient stove called the roaster stove. The grits are fed into a cylindrical metal compartment and placed on a heat source, while being continuously rolled to ensure uniform roasting of the content. It was able to save as much as 10 kg of fuel wood compared with the rural areas where they could only afford the three stone stove.

4.2.4. Milling Roasted Grits into Paste

The milling is conducted to convert the roasted grits into paste for kneading. In the rural sites of the upper west, this was executed in two steps: first, they are pounded in small quantities, at a time, using a mortar and pestle to transform it into a coarse paste. The second step was to grind the coarse paste into a finer paste on a grinding stone. It is a highly labor intensive activity and took approximately 3 h by four adult females to mill approximately 86 kg of the raw kernel into paste. In the urban sites, it was very straightforward because they had an electric powered grinding mill that completed this process within 35 min using up to 4 kWh or 14.4×10^6 J of electric energy (Table 2).

4.2.5. Kneading

This activity is also called the beating stage. The paste is rigorously and continuously stirred, while warm water is continuously added until butter begins to appear on top as a white fluffy substance. This is a painstaking activity that took an average of 2 and a 1/2 h in the northern region and almost 2 h in the upper west region to be completed. Usually, a kneading machine is required for this process; however, none of the locations at which we performed this experiment had this machine.

4.2.6. Heating of Crude Butter and Solidification

The solid white fluffy crude butter is separated and heated in a cooking/iron pot while stirring. The water soon evaporates and the melted solid fluff boils as oil for some time. A considerable amount of caution is exercised for this because any form of over boiling could burn the oil, which affects the final appearance of the resulting butter and consequently affect its marketing potential. This activity took approximately 1 and a 1/2 h at the sites in the upper west region and an average of 2 h at the sites in the northern region. The three stone stoves were used at this stage of the process in all eight sites. This stage was found to be the most fuel wood consuming activity in the shea butter processing chain. Approximately 37 kg of fuel wood was used in the northern region and an average of 30 kg in the upper west. The boiled oil was decanted and impurities were sieved off, and the resulting oil is allowed to solidify overnight. The solidified butter was now packaged for bulk buyers or prepared for retail market.

4.3. Resource Consumption and Output

The data from the experiment process were analyzed to determine the performance of fuel wood, water, and labor on the functional unit (1 kg shea butter) for each experiment site in rural and urban settings across the two administrative regions (northern and upper west). The computations in this article adapted the study previously conducted by Saito [44] on resource use and waste generation on the vast island of Hawaii in five tourism sectors. In this article, 1 kg of shea butter was considered as the functional unit across all locations for computing the input material quantities for rural and urban processing sites. The urban processors in both the upper west and northern regions had access to an electric milling machine for milling the roasted grits into paste. The urban processors used other forms of machinery at various levels of processing which significantly impacted the amount of input resources consumed. The processors in the rural sites identified the milling machine and other machinery including the roaster stove as the most important constraints which makes their operation high resource consuming.

4.3.1. Water

This study found more water consumption in urban sites than in rural sites in both the northern and upper west regions (Figure 4). The lower values mean better performance of the input resource. Tiehisuma is an urban location and was found to have used approximately 5.9 L/kg shea butter compared with 4.8 L/kg shea butter used in Kpalgun, which is a rural site in the same region. However, we realized that similar to all the urban sites, Tiehisuma had an additional operation of sorting and cleaning, which used water equivalent to that of 1.4 L/kg shea butter. The sorting and cleaning was to ensure better quality appearance of the butter to meet urban and export market demands. At the same time, the kneading/beating of the shea emulsion was the most water consuming stage of the processing in both rural and urban experiment sites. The water use at the kneading stage showed rather interesting results in the northern region. Higher quantities of 4.4 L/kg shea butter and 4.2 L/kg shea butter were found in Zagua and Kpalgun, respectively, compared with 4.0 L/kg shea butter and 4.1 L/kg shea butter in the Tiyumba and Tiehisuma urban sites, respectively. Similarly, for the upper west region, water consumed stood at 5.7 L/kg shea butter in Wa-Kpaguri for the entire process compared to 4.3 L/kg shea butter in Zowayeli. Two reasons were provided for this finding during FGDs: the target market for the urban processors is largely middlemen, who bulk the produce for export or for markets in the national capital; thus, they insist on a clear appearance of the butter with no impurities (measure of good quality). The processors argue that they are able to achieve this by washing several times with a considerably greater volume of water. Their rural counterparts usually target the local retail market where there is lesser insistence on a clear appearance as a condition for easy sale. In addition, the rural dwellers expend additional labor scouting for water; therefore, they consciously economize the water use. This is in contrast to the case in urban locations where water is bought from tanker service providers (Figure 4). The target market type for the finished shea butter, the agency by which water comes to the processing site, and the general scarcity or abundance of water were thus found to be important determinants of the total quantity of water used per processing cycle.

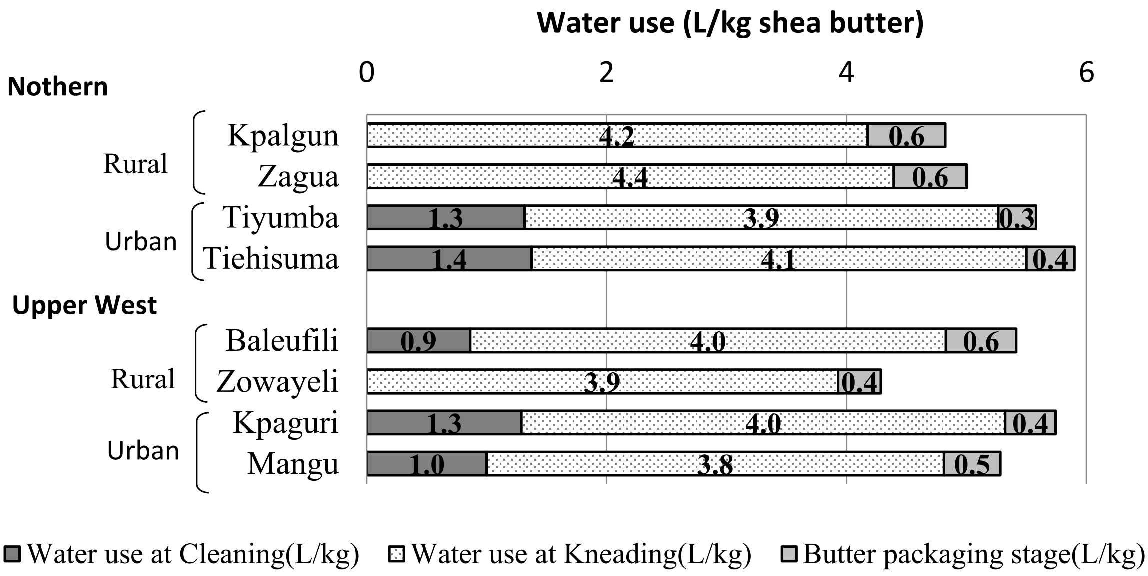

Figure 4. Water use for shea butter output.

Although wastewater was outside the scope of this study (Figure 1), the measurements show that urban areas discharged higher volumes of wastewater at the end of the process compared with their counterparts in rural areas. However, the volumes of water used per site was lower than the volume discharged as wastewater. The water discharged to the ground and was found to be polluted or grey water. Considerable volume of water spillage was observed in all sites, while the water, which was considered to be "dirty," was discharged to the ground. The boiling of crude butter also allowed all the water within the butter to vaporize and escape into the atmosphere. This study had a limitation in accounting for the water balancing.

4.3.2. Energy

The study found that in the rural areas, the energy for processing shea butter largely came from fuel wood and the dry residue produced after extracting the oil from the kernel. The use of crusher, miller, and roaster stove in the urban sites qualifies the processing to be described as semi-mechanized according to a study by Issahaku *et al.* [22], who describe the semi-mechanized processing as the one in which modern machinery is used to conduct some of the processing operations. The urban processors were also found to use higher quantities of shea residue as fuel compared with those used by the rural processors. This introduces some tradeoff between the fuel wood use and electric power consumption in the two urban locations and also between fuel wood use and shea residue.

The fuel wood was used at three processing stages: roasting of the grits, heating water to aid the kneading process, and cooking/boiling the crude butter into oil. Higher quantities of fuel wood are used in the rural areas compared with the urban locations (Figure 5).

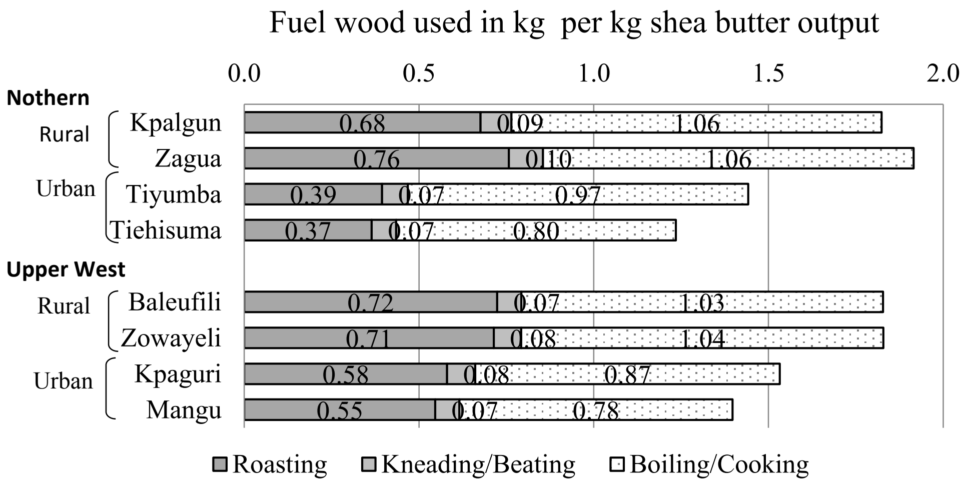

Figure 5. Fuel wood use for shea butter output.

The rural processors used the three stone open stoves, which used more fuel wood, whereas the urban processors used an improved fuel-efficient stove called the roaster stove for the roasting of kernel grits. In the upper west, almost similar quantities of fuel wood were burnt at the roasting and kneading stages. Boiling of the crude butter was the stage at which considerably higher quantities of fuel wood was required across all sites. All the sites used the three stone open stove for this stage and recorded high fuel wood consumption. Tiehisuma recorded the least fuel wood use for the entire process with a cumulative mass of 1.3 kg of fuel wood burnt to produce 1 kg shea butter and 0.80 kg wood for 1 kg shea butter at the boiling stage, but Kpalgun and Zagua used as much as 1.06 kg fuel wood per kg shea butter at the same boiling stage. This is significant because all eight sites used the three stone open stove heath for the stage of the boiling of oil of the butter production.

A similar resource use pattern was recorded for the dry kernel residue used by processors. In this experiment, the residue used was produced in the previous processing cycles because it usually needs a considerably large amount of time to completely dry for easy combustion. The Tiehisuma processing site, for instance, recorded the highest use of shea waste residue of 0.25 kg in producing 1 kg shea butter (Figure 6). It was observed that the urban sites consciously used higher quantities of the shea residue with a principal aim of reducing the use of fuel wood as much as possible. Areas and platforms were consciously created to dry as much of the kernel residue as possible for use as energy.

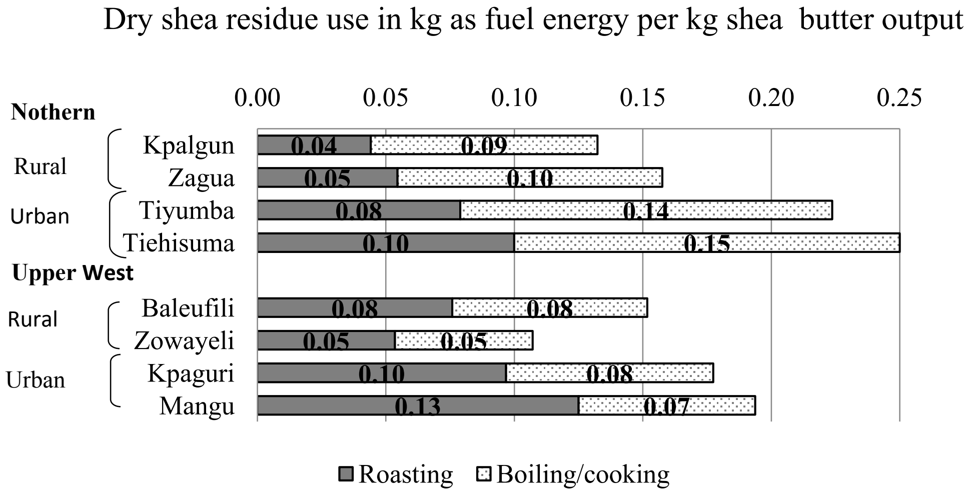

Figure 6. Shea residue for shea butter output.

Using the dried kernel residue as fuel could be a good way of reducing the environmental impacts of fuel wood use in the rural sites. The results however show that processors in the rural areas merely used the residue to facilitate easy combustion of the fuel wood only. The residue was considered as waste and discharged with no intention of being used later as a fuel wood substitute. Consequently, lower quantities were found to be used in the shea butter processing compared with the urban sites (Figure 6). In Tiehisuma, for instance, 0.15 kg shea residue was used per kg shea butter at the boiling stage, which complemented only 0.80 kg fuel wood per kg shea butter. All urban sites recorded a similar pattern of substitutability of input resources, a clear case of more shea residue used, and less fuel wood required.

Electric power consumption at urban processing sites was used for two of the most labor intensive activities in the processing chain: kernel crushing and milling. Electric powered machinery was used in crushing the kernel nuts into grits and milling the roasted grits into paste in all urban experiment sites (Figure 7). We can recognize the tradeoff between electric power consumption and the labor in man-minutes used to perform the activities involving manpower. By using 0.37 mega J of electricity for milling with an electric milling machine, processors at Tiehisuma save approximately 6 man-minutes of labor during milling to produce 1 kg shea butter. None of the rural study sites had access to electricity. This implies availability of electric power becomes a necessary condition for introducing certain machinery in the rural sites. It is however possible to consider diesel powered machines such a grinding mill and crusher as the case may be. This is expected to change the results reflected a reduction in labor resource consumption.

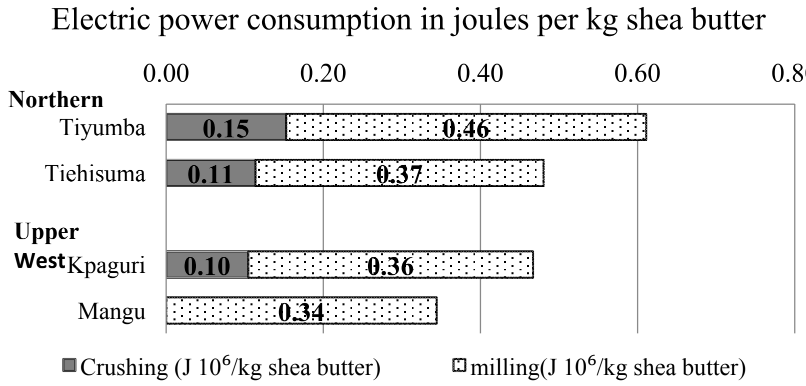

Figure 7. Electric power use for shea butter output.

4.3.3. Labor

The labor in man-hours was higher in the rural locations compared with the urban areas. This was largely because of the kind of processing techniques and equipment used (Figure 8). The rural locations used manual techniques all through the processing cycle, whereas some of the operations, such as milling and roasting, were mechanized in the urban areas, thus significantly reducing the time expended in processing butter at those sites. The study found that the use of machinery, such as an electric crusher and milling machine, saved considerable time and labor in the urban locations compared with the rural locations where mortar and pestle were used for the crushing of kernel into grits. In all the rural sites, the equipment used was a wooden carved mortar from a tree trunk and a pestle for physical pounding to crush the kernel. A grinding stone chipped out of solid rock served as a platform for grinding the roasted grits into paste. This stage was observed to be highly demanding, with regard to physical strength, on the processors and was time consuming.

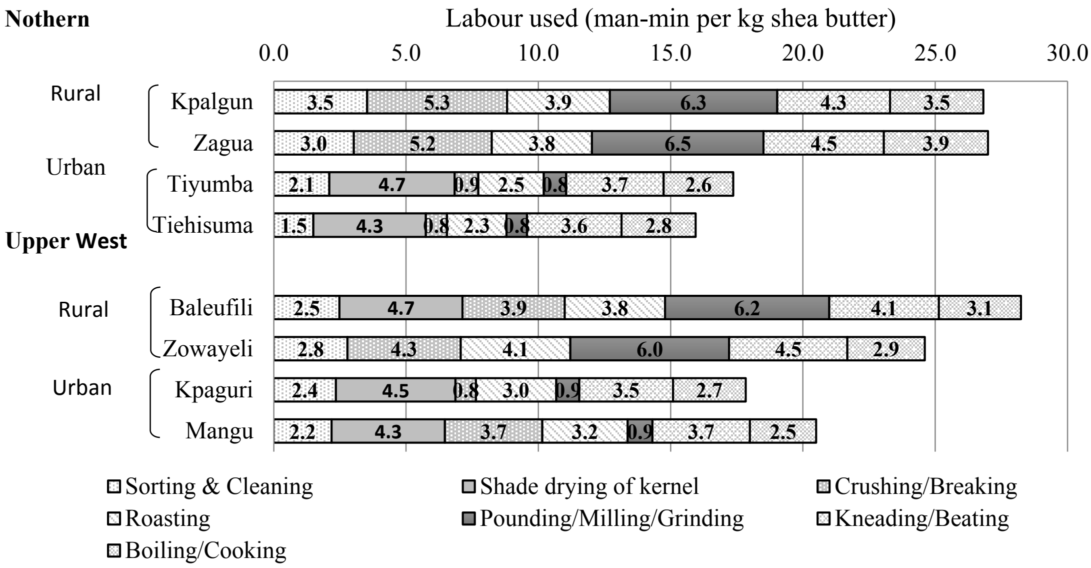

Figure 8. Labor time for shea butter output.

The pounding/milling stage recorded the highest time of labor in rural areas averaging over 6 man-minutes per kg shea butter, while the same activity took under 1 min in urban areas (Figure 8).

Crushing recorded the second highest time in the rural sites: for Kpalgun and Zagua, 5.3 man-minutes and 5.2 man-minutes per kg shea butter were computed, respectively, and for Baleufili and Zowayeli sites, 3.9 man-minutes and 4.3 man-minutes per kg shea butter, respectively, whereas the urban sites took less than 1 min for 1 kg shea butter output. At all these instances, the use of machinery contributed to a good labor performance in the urban locations. Use of machines was therefore found to be a critical determinant of labor performance in shea butter processing. During FGDs, participants explained that pounding or milling into a finer paste and the rigorousness of the kneading activity by a processor were important determinants of the quantity of butter resulting in the end.

However, measuring labor in man-hours posed a number of limitations. The processors operated in highly informal work arrangements in which there were no set standard times allocated for breaks. They typically balanced these recorded processing activities with some household chores such as meal preparation. The time recorded was therefore the upper limit required for executing each activity. It should be noted that the itemized activities were performed by a nonhomogeneous number in each group at a site. The number of workers in a group and skill mix could affect the overall time spent per activity. This analysis merely focused on the overall time spent to produce a unit output irrespective of the number of people or labor force generating the set output.

4.4. Resource Use Linkages and Shea Butter Output Quality

From the illustrations of resource use and their performance on output quality as presented above, we infer that the quantity of water used correlated positively with the amount and quality of butter produced. This was the case at the Tiehisuma and Tiyumba urban processing sites. Simultaneously, we realized that the dry kernel residue can be used as a positive substitute to fuel wood. It is possible to reduce the amount of fuel wood burnt if the use of higher quantities of dry kernel residue is encouraged.

During FGDs, processors mentioned several factors that influence the output quality of butter such as the quality of kernel, the presence of impurities, the level of washing with water, the extent of roasting of kernel grits, and the rigorousness of the kneading. Higher quality raw kernel usually appears bright brown, is filled with sap, and costs more compared with lower quality raw kernel, which appears discolored, disfigured, and is cheaper. Processors usually ensure rigorous sorting at the beginning of the process. In the urban sites, they even wash the raw kernel and shade-dry them before beginning the crushing process to guarantee good quality shea butter. Moreover, they explained that if the roasting is not carefully managed, the grits may burn and eventually discolor the butter. The extent to which these quality measures are taken was found to depend on the target market.

In this study, we further found that in rural sites, the raw material generally was not thoroughly cleaned and was not washed to clean the crude butter, which negatively affected the final quality of the butter which in turn influenced a lower price for the butter. The opposite holds true for the urban sites whose target market is the supply chain for export and the cosmetic industry within the country. The most important determinant of the price for this category of market is the quality of the butter. The better the quality of the butter, the higher the prices offered. The study provides empirical evidence to the existing recommendations that production efficiency could be improved by providing machinery support to processors to help reduce production burden and reduce wastage in resource use [22,45].

5. Summary and Conclusions

This article has presented the results of an input inventory and resource consumption in the shea butter making process in urban and rural Ghana from a firsthand field experimental process. The study design and approach offers a shift from the focus of many other studies on shea, which mainly emphasize the livelihood outcomes or descriptions of associated processes to material quantities. The input quantities used by rural and urban processors were marked and the role of accessibility to improved processing methods and equipment was demonstrated. Issahaku *et al.* [22] determined the limiting factors for input allocative efficiency by ranking responses from processors. They found access to credit and high-equipment cost as the most critical limiting factors. This study gives further information on the specific stages and the exact efficiency level for the input resources.

Using MFA as the main analytical tool, the article has presented resource inventory, the process flow of materials from the environment into the production system, including a series of processes and transformations from kernel to shea butter as direct material outputs for rural and urban contexts in northern Ghana. Thus, the application of MFA to NTFPs and resource use is an added contribution of this study to LCT and sustainable resource management. It is expected to set the stage for further work in defining the environmental impact categories for the resource quantities measured as more processing takes place.

The equipment type and method of processing in rural Ghana are still characteristically nonmechanized and full of drudgery, thereby expending a lot more man-hours and inputs such as fuel wood and labor per unit output in a processing cycle compared with urban processors. Although the cost of production and environmental cost/implication for shea butter processing is beyond the scope of this article, it is safe to infer that it costs more time, labor and fuel wood to process butter in rural Ghana than in urban Ghana. The issues of tradeoffs and complementarity in resource use arise when processing activities such as crushing, roasting, and kneading are mechanized, and labor time can be saved for other productive uses. Simultaneously, roaster stoves and the promotion of the use of shea residue as a fuel source could save considerably large quantities of fuel wood use and reduce production costs in the long run for more sustainable outcomes to the processors and environmental resources.

We recommend a critical analysis of the resource use discussed in this article to derive a basis for equipment allocation to specific processing activities. Processors skills and experience as well as resource use efficiency techniques for the shea butter production industry in rural and urban contexts are critical in defining a sustainable operation for the shea butter industry. This study sets a foundation for further research on the environmental effect of resource use and improving the efficiency of resource use in operations of value addition to NTFPs, in particular and agricultural commodities at large. The limitations of this study and the gaps identified within the boundary set will need further research in order to obtain information on sustainable policies regarding resource use and optimal utilization of shea for sustainability.

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Author Contributions

Godfred Jasaw and Osamu Saito designed this research; Godfred Jasaw carried out the field research, analyzed the data and wrote the initial draft manuscript. All authors read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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