The Economic Viability of Small-Scale Shea Butter Processing in Northern Ghana

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April 2000.

NRI Report Number 2521

Report prepared for the Crops Post Harvest Programme of DFID and TechnoServe, Ghana

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Table of Contents

Acknowledgements

The authors wish to express their gratitude to TechnoServe, Ghana and the DFID Crop Post Harvest Programme for their support and funding of this study. Thanks are also due to the various players who contributed to this project; particularly Mr. Peter Donkor of the Technology Consultancy Centre who coordinated the technical trials, and Dr. W. Ellis of the Biochemstry Department, UST who conducted analysis on the quality and shelf life of shea butter. A special mention must go to Johnson Panni of the Ministry of Food and Agriculture who carried out a splendid job of monitoring the village pilot under extremely taxing conditions. Finally, thanks are due to Seth Gogoe for all his hard work, enthusiasm and dedication to the project. Last but not least, many thanks to Angela Asante and Nii Chinnery of TechnoServe for coordination of activities and collection of market and financial data. We couldn't have done it without you!

Exchange rate US$1 = 2,300 cedis (May 1999)
US$1 = 4,000 cedis (January 2000)

Abbreviations

CBE	Cocoa Butter Equivalent
CPHP	Crop Post Harvest Programme
FFA	Free fatty acid
FOB	Free On Board. The point at which a commodity is on the ship at the port of origin.
GRATIS	Ghana Regional Appropriate Technology Industrial Service
ITTU	Intermediate Technology Transfer Unit
MoFA	Ministry of Food and Agriculture
NRI	Natural Resources Institute
OEE	Oil extraction efficiency
TNS	TechnoServe
TCC	Technology Consultancy Centre
UST	University of Science and Technology, Kumasi

Summary

This study was conducted for TechnoServe and the DFID Crop Post Harvest Programme (CPHP). It examines the profitability of small-scale shea butter processing using a hand operated bridge press technology, by analysing its financial and technical performance. The study also assesses whether a shea processing business can be effectively managed by rural women's groups.

In previous work, the bridge press technology was shown to offer several technical advantages over the traditional method of processing shea, by increasing labour productivity, conserving water and firewood and producing a higher quality butter. However, it also became apparent that the bridge press offers little financial advantage over the traditional method, as returns from processing for the domestic market are very low and market demand is limited. Furthermore, the traditional technique meets the specifications of most domestic consumers, providing little incentive to use the bridge press.

A recent market study funded by the CPHP concluded that international demand for shea butter from cocoa butter equivalent manufacturers is likely to increase over the next few years. This suggests that there is a potential for small-scale shea butter processing to become a profitable business if output can be increased, cost of production reduced and quality improved, and the product targeted at the international market.

Financial analysis of the bridge press technology showed that despite significant increases in labour productivity over traditional methods of extraction, the scale and technical efficiency of the technology are not great enough to achieve profitability at the current level of international prices. FOB price of crude shea butter ranged between US$600 and $950/MT during 1999, whilst our financial model returned a production cost of $940/MT. Unless international prices rise, the bridge press technology will not be economically viable. The European shea market was unusually depressed during 1999 due to large stocks held from 1998, coupled with the sharp fall in cocoa prices. However, there are strong indications that international demand for shea butter processed at origin is set to grow. This view is supported by the plans of a multi-national company to set up a large-scale shea processing plant using the bridge press technology in northern Ghana in the near future.

The women's groups involved in the pilot study lacked the management skills and entrepreneurship to manage the processing operation as a small-scale business, despite technical assistance and business advice from TechnoServe. The women lacked commitment to the project, manifested by high levels of absenteeism, and resulting in low labour productivity and level of output. Social events, household duties, childcare and farming all compete for women's time. Out of a theoretical number of 109 working days, processing took place on 41 days, representing 38% of total processing time. The level of output attained during the pilot project is equivalent to an annual production of 8.5 metric tonnes. This is too small a volume to be of interest to any commercial buyer.

Signficantly, both the miller and the secretary supporting the groups were male. This demonstrates that women lacked the confidence and ability to take on roles which are generally regarded as a male preserve. The women were also illiterate, which which excluded them from participating in the management of the business. These findings are consistent with those of Stringfellow et al (1996), who concluded that group management of businesses is usually not a successful model in Sub-Saharan Africa. Our findings support the view that small-scale businesses operated by individual entrepreneurs stand a better chance of success than group managed enterprises. An individual small-scale entrepreneur is still likely to require assistance with market linkages and access to working capital. These are potential areas for TechnoServe assistance.

However, in the light of new large scale processing interests in Ghana, the competitiveness of any small-scale shea processing business using bridge press technology must be questioned. It may well be more advantageous to set up a support facility to service the requirements of a large scale processor and from which those traditionally engaged in the shea industry can still derive benefits.

An unexpectedly large number of technical difficulties were encountered during the course of the pilot. Many of these were a result of equipment malfunction. Locally fabricated equipment was found to be of inappropriate design and inconsistent quality. GRATIS is instigating a quality assurance programme for ITTU management in an attempt to ameliorate this deficiency.

The technical trials identified a number of parameters which impact on extraction efficiency of the bridge press and quality of butter. Most importantly, the bridge press does not significantly increase the technical efficiency of the traditional process. Both methods have a similarly low oil extraction efficiency, typically in the region of 31% (butter yield based on kernel weight) under field conditions. As oil content of the shea kernel is in the region of 54%, it is clear that a large proportion of the oil remains unavailable.

The bridge press method is also highly temperature and moisture dependent. These parameters require careful control to optimise extraction efficiency and this proved difficult under field conditions. The low extraction efficiency was further exacerbated by cold weather conditions, which made it difficult to maintain the shea paste at the required temperature. In order to improve extraction efficiency, the technology would have to incorporate a heating device to maintain paste at an optimum temperature. This is particularly important during cold weather.

It was also found that the optimum moisture content (and extraction efficiency) varied with the type of press used. Although the MoFA (lower pressure) press gave slightly higher yields, it operated at a higher optimum moisture content, which resulted in higher levels of moisture and extraneous matter in the extracted oil. The TCC (higher pressure) press is therefore recommended for processing of shea butter. It gives a slightly lower yield, but produces oil of a higher quality.

Old kernels had a higher oil extraction efficiency (OEE) than new kernels due to their lower moisture content. Unroasted kernels had a higher OEE than roasted kernels. A correlation between paste particle size (fineness) and OEE was also observed. It is therefore important to ensure that kernels are finely milled in order to enhance oil extraction efficiency.

The quality of 20 butter samples processed under different experimental conditions was generally good. Moisture contents were low, ranging between 0.07% and 0.78%. These values fall well within the quality specifications of major European buyers. Roasting of kernels had a significant effect in reducing the moisture content of the extracted butter. Moisture content of extracted butter was found to increase with increasing moisture level of the paste at pressing. As paste moisture increased from 10% to 20%, moisture content of butter increased from 0.12% to 0.61%.

Free fatty acid levels of the 20 samples analysed ranged between 0.51% and 1.75%. Again, these values are well within the quality specifications of major European buyers. Butter from old kernels had significantly higher levels of free fatty acids than oil from new kernels. However, roasting appeared to have an inhibitory effect on free fatty acid formation in new kernels. Free fatty acid levels in butter extracted from roasted new kernels were significantly lower than those from unroasted new kernels.

The use of a small-scale continuous screw expeller for the extraction of shea butter was investigated. However, in the preliminary trials, it was not possible to raise the temperature in the extraction chamber to the level required (above 80oC) for efficient extraction of butter.

The report recommends:

- Examination of alternative small-scale shea processing technologies (e.g. hydraulic press, screw expeller), primarily in terms of their technical efficiency. An extraction efficiency of between 40% and 45% (as opposed to the 31% obtained with the bridge press) would probably make small-scale shea processing marginally profitable at current international prices.

- Research into shea nut harvesting, handling and storage practices to improve the quality of butter produced. Improving nut quality would be of direct benefit to the traders and intermediaries who will be commissioned to supply large scale processors with high quality nuts.

- Studies on butter shelf life to ascertain the critical points at which deterioration occurs and how it can be most effectively prevented. This study would inform the selection of environmentally sustainable handling and processing practices which do not rely on the use of firewood.

- A review the profitability of small-scale shea butter extraction once the effects of recent exchange rate adjustments have been fully felt.

1. Introduction

The production of shea butter is an important income earning activity for many rural women in northern Ghana and for some women, it is their only source of income. However, the traditional method of processing is an extremely arduous, time consuming activity, which in addition uses large quantities of water and firewood, scarce natural resources in northern Ghana.

During 1995/6, Natural Resources Institute (NRI) in collaboration with the Technology Consultancy Centre (TCC) and the Intermediate Technology Transfer Unit (ITTU) developed and field tested an alternative technology for shea butter processing based on a manually operated bridge press. The technology offers several advantages over the traditional processing method. It greatly reduces the amount of time, manual labour and water, and eliminates the need for firewood (Hammond et al, 1996). There are also indications that the bridge press produces a higher quality butter with a lower free fatty acid and moisture content.

However, research as well as practical field experience have demonstrated that women receive very low returns from small scale shea butter processing, and that the bridge press offers little financial advantage over the traditional method (Gray, 1997). Although the press appears to produce a higher quality product, the traditional technique meets the specifications required by most buyers and with a scarcity of price premia for quality which exceeds minimum specifications, there may be little incentive for small scale processors to use the bridge press (Collinson, 1999).

The bridge press does however substantially increase labour productivity, suggesting that its adoption could allow women processors to increase their output of shea butter, thereby offsetting the prevailing low margins in the industry with higher turnovers. However, women processors generally have little excess cash to use as working capital and consequently cannot build sufficient stocks of shea nuts to increase their butter output. To overcome the lack of working capital, there may be potential for linking small scale processors with export markets. This would help processors to produce high quality shea butter in sufficiently large volumes to interest commercial buying agents(Collinson, 1999).

To gain a better understanding of the potential profitability of the sector, NRI conducted a study on shea butter markets, both domestic and international (Collinson, 1999). TechnoServe (TNS) also commissioned market research in this area, to assess whether shea butter processing should be promoted as a viable business opportunity to TechnoServe assisted groups.

The NRI study concluded that international demand from Cocoa Butter Equivalent (CBE) manufacturers for shea butter is strong and likely to increase over the next few years, principally due to growing demand by the confectionery industry in Eastern Europe, Japan and Europe. In addition, tight environmental legislation in Japan and Europe is persuading buyers to purchase shea butter in West Africa, rather than import shea nuts and extract shea butter themselves. These market developments are being reflected in Ghana, where the leading processors have plans to expand their production and supplies of crude shea butter can not keep pace with demand.

However, the Ghanaian shea butter processing industry is constrained by poor access to shea nut producing areas, a lack of working capital amongst small scale processors and on occasion, by indifferent quality. The benefits that small scale processors receive from market growth will thus be limited unless processors can access more working capital.

Several companies and organisations which have recently entered the export business complain that prices offered by importers are too low. The NRI study suggests that this is a cost of production problem rather than a price problem. New entrants may not yet have rationalised their production systems or exploited economies of scale. Kassardjian, the company with the longest experience of processing and exporting shea butter, does not complain about export prices.

The present study, jointly funded by TechnoServe and the DFID Crop Post Harvest Programme, examined the profitability of small scale shea butter processing using the bridge press technology (the terms of reference appear in Appendix 1). It pilot tested the financial and technical performance of a small scale shea butter processing business operated by rural women. The pilot assessed whether small scale shea butter processing can become a profitable business for rural women by increasing technical efficiency and level of output, and marketing the product through appropriate channels (brokered initially through TechnoServe). The study also examined the role which NGOs such as TechnoServe can play to encourage greater integration of small scale processors with shea butter buyers.

On-station technical trials at the TCC were run concurrently with the processing pilot. The objective of the trials was to assess a variety of technologies and processing practices in terms of their technical efficiency and product quality for small-scale shea butter production. The trials were also undertaken in order to dispel local misconceptions (documented by Bosuner, 1998) surrounding the efficiency of the bridge press technology and in particular, the quality of its product.

Details of the methodology followed both in the village and on-station trials appear in Appendix 2.

2. Principal Findings

2.1 Organisation of shea butter processing business

Management of business

The pilot was conducted between 17th July and 22nd November 1999, a total of 131 days. However, the first two weeks were used as a refresher course for the women. The training programme organised before the start of the pilot was poorly attended, and it was evident at the beginning of the pilot that many of the women were not conversant with the technology. Within this period, the theoretical number of working days (based on the assumption that there is no production on market days, held every sixth day) should have been 109. In fact, the actual number of working days was 41, representing 38% of the time theoretically available for processing.

A number of reasons contributed to this disappointing performance. A major cause was persistent rainfall, which resulted in flooding and sinking of the concrete platform holding the diesel engine. The platform had to be reinforced and this led to a long stoppage in the work. The presses were installed outdoors, with a tarpaulin for cover. Once again, the persistent rainfall resulted in frequent stoppages, as there was inadequate shelter for operators, equipment and product. An aluminium roof was later erected to minimise disruption to the work. Stoppages also arose due to equipment breakdown. These are described in more detail in Appendix 3.

However, many stoppages were due to absenteeism by the women. Participation in social events such as funerals, weddings and out-doorings (an infant ceremony) is an integral part of the culture, and during such events, processing came to a halt, as all the women in the village were involved. The start of the pilot coincided with the main planting season, which also competed for women's time. In addition, it became evident that some of the women lacked commitment to the pilot and did not honour the production schedule which had been agreed upon. This put an additional strain on those women who were keen to participate, as they had to work more frequent shifts to cover for their absent colleagues. The groups from Chanzegu showed less commitment to the pilot than their colleagues from Kanfiehiyili. This may be partially attributed to the siting of the equipment in Kanfiehiyili. The location of the equipment had been a hotly debated issue during the setting-up of the pilot, as both villages wanted control of the equipment. With the processing centre sited at Kanfiehiyili, the Chanzegu groups had to walk approximately 1.5 km to reach the processing site, whereas Kanfiehiyili women had the equipment on their doorstep. It is also likely that the Chanzegu groups felt a lack of ownership of the project, because they had restricted access to the processing site.

On working days, women began processing by 9.00 a.m. Work could not begin earlier, as the women were busy in the mornings preparing food for their families. It took approximately 45 minutes to clean the equipment and set up for the day's production. The women worked all day, with one hour's break for lunch, ending at approximately 6.30 p.m. The average number of bags of kernels processed per day was 2.9, but the maximum daily level of production was 4 bags. This level of output was possible when production continued throughout the day and was unaffected by stoppages. Although the bridge press removes much of the drudgery associated with the traditional method of processing, the women (particularly the elderly and pregnant) nonetheless found the operation of the press tiring and had to take frequent rests. Nursing mothers also had to take frequent breaks to feed their babies. This explains why the processing day was so long.

In total, 3.1 metric tonnes of butter was produced during the pilot from 10.0 metric tonnes (119 bags) of kernels. The remaining 16.9 metric tonnes (201 bags) procured for the trial by TechnoServe were not processed due to delays in the production schedule detailed above and the lack of a ready market. This level of output is equivalent to an annual production of 8.5 tonnes of butter, based on an average extraction efficiency of 31%.

Performance of processing equipment

The relatively cold weather during the rainy season adversely affected the extraction efficiency. The temperature of the milled paste is critical to achieving a satisfactory yield of butter and should be above 60°C for optimum extraction efficiency. In cold weather (temperatures of 25°C to 30°C), the mill chamber had to be heated by a charcoal burner prior to milling, for the paste to achieve the required temperature. Similarly, the press cage had to be heated to prevent it absorbing heat from the paste. These additional processing steps increased the cost of production and reduced butter yield. The average extraction efficiency was 31%, which is significantly lower than the extraction rates obtained in the TCC trials (see below). In these trials, at optimum levels of moisture and temperature, average yields in excess of 35% were recorded.

In terms of equipment, the rate-limiting step to increased productivity was the press. It was observed that both crusher and corn mill were under utilised when two presses were in simultaneous operation. An additional press was therefore installed, bringing the total number of presses to three. However, to optimise efficiency, a fourth press should be installed in order to match milling capacity with pressing capacity.

It became apparent that small-scale equipment manufactured by local fabricators is not produced according to standard specifications and lacks uniformity. Wide variations in design and quality were observed. For example, the bridge press manufactured according to the TCC design was quite different to the one later built by the ITTU. Different construction materials are also used. The TCC press was made with stainless steel whilst mild steel was used for the ITTU press. The mild steel began to rust and contaminated the butter, imparting a dark, reddish colour. By contrast, the TCC press which was fabricated from stainless steel produced butter which was cleaner, with a light yellow colour. In general, the equipment was found to be unreliable and suffered numerous breakdowns. In some cases, the original design was defective and had to be modified. It also proved difficult to obtain reliable after-sales service from the ITTU in Tamale. Eventually, a private fabricator (Danlari Metal Works Ltd., Tamale Industrial Area) was commissioned to carry out necessary repairs, in order not to further delay the trials. He proved to be reliable and effective.

The Ghana Regional Appropriate Technology Industrial Service (GRATIS) supports the ITTUs which operate in all the regions of the country. GRATIS is aware of the inconsistent quality of equipment manufactured by the ITTUs and is planning to set up a quality assurance training programme for ITTU managers to address these issues.

A detailed record was kept of routine maintenance, purchase of spare parts, design defects and breakdowns, in order to identify "weak spots" in the processing operation, and assess the resources necessary (in terms of cost, time and expertise) to keep equipment functioning satisfactorily. This information will be of value to other small-scale processing businesses. The main breakdowns, repairs and modifications are detailed in appendix 1.

Marketing of shea butter

TechnoServe undertook to pay the women a fixed processing fee and took responsibility for marketing all the butter produced. This was done to cushion the women against the risks of selling to a European market which had been unusually depressed during 1999.

Prices were depressed in 1999 mainly because cocoa prices were low and European shea nut buyers were holding considerable stocks from 1998. The fall in cocoa prices also contributed to the decreased demand for shea butter as a cocoa butter equivalent (shea's major market). During the 1999 season, FOB prices for nuts were on average $218/MT, compared to $290/MT in 1998 and $250/MT during the 1997 season. Corresponding producer prices in 1999 ranged between $120-$150/MT, a 25% decrease from $160-$208/MT earned by shea collectors in the previous year. The FOB price of crude shea butter ranged between $600 and $950/MT during 1999 (Helen Kassardjian, pers. comm.). Therefore, export orders for shea nuts and shea butter were limited and prices offered by local buyers were low. These events, coupled with local misconceptions regarding the quality of bridge pressed butter, made efforts to secure a market more challenging than anticipated.

Olam Ghana Ltd. initially agreed to purchase the bulk of bridge pressed butter produced from the trials, pending confirmation that the butter met their export specifications. However, Olam quoted an unusually low moisture content (0.05%), which was approximately one tenth of the standard industry specification in Ghana. At the time, the moisture content of the bridge pressed butter produced at the TCC was approximately 0.25%. Although efforts were made to reduce the moisture level, technical officers from the Ministry of Food and Agriculture assisting with the trials indicated that the introduction of heating procedures may adversely affect butter quality. It was later suspected that the buyer intentionally quoted an unattainable quality specification to nullify his offer, due to the impending depression of the shea market.

After arrangements with Olam did not materialize, TechnoServe held discussions with JEBA/Ghana Ltd., to market the butter. JEBA, a local manufacturer of hair/skin care products, is interested in using bridge pressed butter in the production of their shea butter body cream. After conducting a quality assessment on several trial samples, JEBA ascertained that the bridge press butter commanded a higher quality (i.e. lower free fatty acid and moisture content) and a smoother texture than traditionally processed butter. As a result, the company purchased approximately 200 kg of butter at ¢3,000/kg as a trial production order. In March 2000, JEBA placed a tentative order for an additional 200 kg of butter. TechnoServe is currently holding discussions with JEBA representatives to explore the possibility of a longer-term service contract.

TechnoServe is also exploring the possibility of marketing the remaining bridge pressed butter to a number of local companies who have expressed some interest in the product. These include Scotty Ltd. – a local pharmaceutical company and PZ and FC Perfumery – a large day spa that distributes several skin and body care products domestically. Scotty Ltd. has analysed samples from the trial and have endorsed the superior quality of the bridge pressed butter. However, whatever the outcome of future negotiations, overall demand from the local market is likely to remain very small.

TechnoServe recently initiated discussions with representatives of the Shea Butter Company (US) – producers of "Crushed Shea Butter", a body cream made from 100% pure shea butter. Representatives of the company have expressed interest in using bridge pressed butter in their product line and possibly developing a facility for refining crude shea butter in Ghana. If their plans materialise, the refinery may uncover new opportunities for bridge pressed butter in local industries and provide a high value product for export market. Further discussions with the Shea Butter Company are pending their analysis of the butter.

The Government of Ghana's prevailing policy on primary commodities has stressed the need to expand value-added opportunities for shea. As a result, local processing ventures may be able to tap into financial and technical support from government institutions for shea processing.

3. Financial analysis

3.1 Description of financial model

Table 1 describes a financial model of a notional small-scale shea butter processing enterprise. The business is located close to Tamale in order to minimise transport costs both of shea nuts to the plant and of shea butter to the purchaser. We have assumed that the business sells butter twice a month to one of the shea butter exporters located within the Tamale area.

The business operates the same types of processing equipment used in the TNS/NRI village based trials. However, the number of bridge presses has been doubled to four in order to match milling capacity with pressing capacity. With only two presses, the milling machine lies idle for half the working day.

The processing plant operates for eleven and a half months a year (the remaining time is spent on routine maintenance). Ensuring a continuous supply of raw materials for that length of time requires a careful purchase and storage strategy in order to minimise costs. New season shea nuts become available in June, although exporters are unwilling to purchase at this time because the new nuts tend to have a high moisture content. According to traders interviewed during fieldwork in Tamale, shea nut prices remain constant throughout June and July, start to rise in August (when the shea nut exporters start to buy) and continue to rise until they reach a peak in November/December/ January. Typically, the marketing season's opening price rises by between 50 and 100% during the six-month period in which the major exporters purchase nuts[1]. Figure 1 compares a 50% seasonal price rise with carry costs (the costs of storage) for a twelve-month period. The graph is drawn using indices (July =100) in order to simplify the comparison. Costs of storage were calculated using an assumed 20% real weighted cost of capital and a physical storage cost of 1% of the July value for every month of storage.

Although highly simplified, Figure 1 suggests that purchasing nuts during July and bearing the costs of storage for the rest of the year is considerably cheaper than buying shea nuts on the open market when required throughout the year. Our model

[1] The project monitored shea nut wholesale prices in Tamale between May 1999 and February 2000. Unfortunately 1999 proved a very poor year for shea purchasing. Ghana's shea nut exporters purchased very small quantities of nuts, mainly because European buyers were holding considerable stocks from 1998. Consequently prices failed to rise between August and January in the usual way.

therefore assumes that the manager of the processing plant purchases eleven and half month's processing stocks in July, before the exporters start to buy and prices rise.

All other assumptions used in the model are contained in Appendix 4.

3.2 Financial results

Table 1 paints a poor future for the processing enterprise. As currently structured, the business would lose nearly US$16,000 a year, or, put another way, US$340 for every tonne of butter that it produces.

Could anything be altered to turn the situation around? Regarding revenue, the price that the business receives for its butter would have to increase from our current estimate of US$600/MT to US$950/MT before the business could break even. However, this assumes that the local prices of shea nuts would not increase in line with international butter prices. If the two are closely linked, increased revenue from higher butter prices would be absorbed by higher raw material costs.

The business could investigate ways of reducing costs. For instance improved technical efficiency could help to increase labour productivity and the yield of butter from shea nuts. However, the improvements would have to be large before profitability could be realised. For instance, cutting the number of workers employed on the bridge presses by half (while maintaining output) and increasing the butter yield from 31 to 40% would still not bring the business into profitability.

Perhaps the only hope of profitability would come from increasing both the technical efficiency and the scale of the operation. However, such a business would require considerable capital investment and would therefore be out of the reach of small businessmen. Furthermore, the increased scale of the enterprise would put it in direct competition with established commercial butter processors in northern Ghana.

A key objective of this project is to assess whether the bridge press can make small-scale shea butter manufacturing profitable, thereby allowing small businesses to benefit from forecasted increases in international demand for shea butter processed at origin. Although the bridge press significantly increases labour productivity over

Figure 1. The Case for Storage: Seasonal Shea Nut Price Rises vs Carry Costs

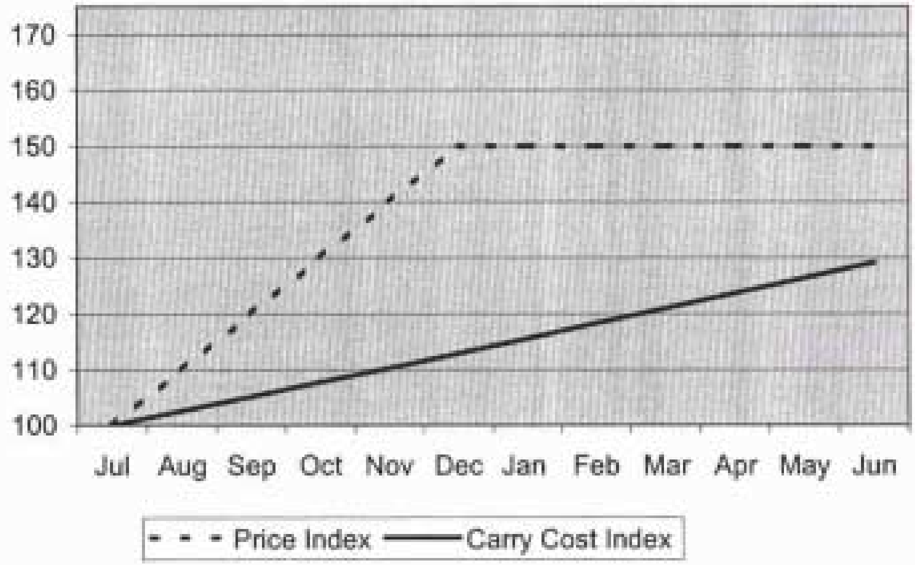

Table 1. Analysis of profitability

	$ per annum	$ per tonne of product	% of revenue
Operating costs - variable:			
Raw material	22,720	490.24	82%
Transport of nuts to processing site	747	16.13	3%
Fuel	843	18.19	3%
Miscellaneous processing materials	2,840	61.29	10%
Direct labour	6,843	147.64	25%
Packaging of butter	695	15.00	3%
Transport of butter to exporter's depot	232	5.00	1%
Sub-total variable costs	**34,921**	**753.50**	**126%**
Operating costs - fixed:			
Management ($200/month)	2,400	51.79	9%
Annual processing site rent	20	0.43	0%
Storage facilities	230	4.96	1%
Maintenance of machines	345	7.44	1%
Sub-total fixed costs	**2,995**	**64.62**	**11%**
Sub-total operating costs	**37,916**	**818.12**	**136%**
Contingency - 5%	1,896	40.91	7%
Total operating costs	**39,812**	**859.03**	**143%**
Capital costs	3,748	80.88	13%
Total annual costs	**43,560**	**939.91**	**157%**
Annual revenue	**27,807**	**600.00**	**100%**
Profit (loss) before tax	**(15753)**	**(339.91)**	

traditional methods of extraction, the scale and technical efficiency of the technology are not great enough to achieve profitability.

Perhaps the only ray of hope for small-scale shea butter extraction is the recent devaluation of the Cedi. Until the middle of 1999, the Ghanaian government maintained the value of the Cedi at artificially high levels by trading on the foreign exchange markets. The government abandoned this practice on the advice of several domestic and international organisations in order to maintain foreign exchange liquidity and to provide greater Cedi earnings to exporters. The full impact of the devaluation has yet to be felt, and consequently we have not included the effects in our financial model. However, the profitability of small scale shea butter extraction should be reviewed once stability has returned to exchange rates and the full effects of devaluation have fed through to the domestic economy.

4. On-Station Technical Trials of Processing Equipment

The purpose of the on-station trials was to test whether technical innovation and optimal technical management could have a significant impact on enterprise profitability. Details of the trial methodology and results appear in Appendices 2 and 4 respectively.

The key findings were:

- Optimal conditions created during the on-station trials enhanced the performance of the extraction equipment. The type of bridge press used in the village trials reached a maximum yield of 37% (compared with 31% achieved in the village trials), while a type of bridge press designed by MoFA staff, achieved 38%.

- Paste moisture and temperature are critical in ensuring maximum extraction efficiency. However, the optimum moisture content (and extraction efficiency) was found to vary with the type of press used. Although the MoFA (lower pressure) press gave slightly higher yields, it operated at a higher optimum moisture content, which resulted in higher levels of moisture and extraneous matter in the extracted butter. The TCC (higher pressure) press is therefore recommended for processing of shea butter. It gives a slightly lower yield, but produces butter of a higher quality.

- Old kernels had a higher OEE than new kernels due to their lower moisture content. Unroasted kernels had a higher oil extraction efficiency (OEE) than roasted kernels. A correlation between paste particle size (fineness) and OEE was also observed. It is therefore important to ensure that kernels are finely milled in order to enhance oil extraction efficiency.

- The quality of 20 butter samples processed under different experimental conditions was generally good. Moisture contents were low, ranging between 0.07% and 0.78%. All but four samples had moisture levels below 0.50%. These values fall well within the quality specifications of major European buyers. Roasting of kernels had a significant effect in reducing the moisture content of the extracted butter. Moisture content of butter was found to increase with increasing moisture level of the paste at pressing. As paste moisture increased from 10% to 20%, moisture content of butter increased from 0.12% to 0.61%.

- Free fatty acid levels of the 20 samples analysed ranged between 0.51% and 1.75%. Again, these values are well within the quality specifications of major European buyers. Butter from old kernels had significantly higher levels of free fatty acids than butter from new kernels. This was observed for both roasted and unroasted kernels. However, roasting did appear to have an inhibitory effect on free fatty acid formation in new kernels. Free fatty acid levels in butter extracted from roasted new kernels were significantly lower than those from unroasted new kernels.

- No significant difference was found between levels of extraneous matter in butters extracted at paste moistures of 10% and 12%. But at 15%, extraneous matter increased, especially when the kernels were roasted before milling. Butters obtained using 10% and 12% moisture pastes were cleaner, with lower levels of suspended particles, than those extracted at moistures of 15% and above.

- A relationship was observed between paste moisture at pressing and number of press bags broken per extraction trial. Broken bags result in contamination of butter and high levels of extraneous matter. More bags were broken during pressing at 15% paste moisture than at 12%. Roasting also appeared to increase the breakage of bags.

- The use of a small-scale continuous screw expeller for the extraction of shea butter was investigated. However, during the preliminary trials, it was not possible to raise the temperature in the extraction chamber to the level required (above 80^{o}C) for efficient extraction of butter.

Despite pointing to the possibility of improved technical performance under factory conditions, these findings fall short of offering a solution to the unprofitability of small scale shea butter extraction. As indicated in the section on financial analysis, the butter yield of the bridge press would have to increase to over 40% before a profit could be realised. Clearly, even under the best conditions, bridge presses are not capable of achieving such yields.

5. Conclusions

The European shea market suffered from lack of demand during 1999 due to large stocks held from over 1998, coupled with the sharp fall in cocoa prices. This made it very difficult to find a market for butter processed by the women's groups and most of the 3.1 MT produced remains unsold, in storage. A further 16.9 MT of nuts procured by TNS was not processed due to delays in the production schedule, coupled with the lack of a ready market. However, there are strong indications that international demand for shea butter processed at origin is set to grow. This view is supported by the plans of a multi-national company to set up a large-scale shea butter processing plant using the bridge press technology in northern Ghana in the near future.

There is also potential for expanding the domestic market for shea butter which is primarily used by soap and skin cream manufacturers. Local industries have expressed interest in the bridge pressed butter, but the size of this market is limited.

Financial analysis of the bridge press technology showed that despite significant increases in labour productivity over traditional methods of extraction, the scale and technical efficiency of the technology are not great enough to achieve profitability at the current level of international prices. FOB price of crude shea butter ranged between $600 and $950/MT during 1999, whilst our financial model returned a production cost of $940/MT. The recent devaluation of the Cedi may have a positive effect on the profitability of small scale shea butter extraction enterprises. Profitability should be reviewed once the full effects of devaluation have been felt.

The women's groups involved in the shea processing pilot lacked the management skills and entrepreneurship to manage the processing operation as a small-scale business, despite technical assistance from the MoFA monitor and business advice from TechnoServe. The women lacked commitment to the project, manifested by high levels of absenteeism, and resulting in low labour productivity and level of output. Social events such as funerals, weddings and outdoorings are an integral part of the culture and compete for women's time. In addition, women are responsible for household duties, childcare and farming. It is therefore not surprising that they were unable to devote their time to the processing business according to the original agreement. Out of a theoretical number of 109 working days, processing took place on 41 days, representing 38% of total processing time. The level of output attained during the pilot (3.1 MT) is equivalent to an annual production of 8.5 metric tonnes. This is too small a volume to be of interest to any overseas commercial buyer.

Significantly, both the miller and the secretary supporting the groups were male. Milling is generally regarded as a male preserve and the women clearly lacked the confidence to take on this role. The women forming the groups were illiterate and the male secretary was appointed on account of his literacy. This highlights that a minimum level of education is a prerequisite to managing a successful business.

The findings from this study are consistent with those of Stringfellow et al (1996), who concluded that group management of businesses in Sub-Saharan Africa is only viable when strong management skills exist, strong social cohesion leads to a unity of purpose, and business and technical functions are uncomplicated. Our findings support the view that small-scale businesses operated by an individual entrepreneurs stand a better chance of success than most group managed enterprises. However, an individual small-scale entrepreneur is still likely to require assistance with market linkages (particularly international ones) and access to working capital. These are potential areas for TechnoServe assistance.

In the light of new large scale shea butter processing interests in Ghana, it may well be more advantageous to set up a support facility to service the requirements of a large scale processor and from which those traditionally engaged in the shea industry can still derive benefits.

An unexpectedly large number of technical difficulties were encountered during the course of the pilot. Some of these can be attributed to the persistent rainfall that disrupted work on numerous occasions. However, many of the stoppages were a result of equipment malfunction. Locally fabricated equipment was found to be of inappropriate design and inconsistent quality. GRATIS is instigating a quality assurance programme for ITTU management in an attempt to correct this deficiency.

The technical trials at TCC identified a number of parameters which impact on extraction efficiency of the bridge press and quality of butter. The results provide evidence that local misconceptions surrounding the efficiency of the bridge press technology and in particular, the quality of the butter (Bosuner, 1998) are unfounded.

The trials confirmed the advantages of the bridge press technology documented in previous work. Labour productivity is certainly increased, and the drudgery associated with the traditional process is at least partially alleviated. Despite the reduction in drudgery, women who participated in the field trials (particularly the pregnant and elderly) still found the technology arduous and were forced to take frequent rests, reducing labour productivity. The technology saves large quantities of fuel wood and water, natural resources which are scarce in northern Ghana. Finally, the bridge press method results in a high quality product. This has been independently verified by a number of manufacturers, both domestic and international, who have analysed samples of bridge pressed butter and expressed satisfaction with the quality of the product (TechnoServe data).

However, the bridge press does not increase the technical efficiency of the traditional process. Both methods have a similarly low oil extraction efficiency, typically in the region of 31% (butter yield based on kernel weight) under field conditions. As oil content of the shea kernel is in the region of 54%, it is clear that a large proportion of the oil remains unavailable. In addition, the bridge press method is highly temperature and moisture dependent. Laboratory trials routinely obtained extraction efficiencies in excess of 35% by careful control of moisture and temperature. These parameters proved less easy to control under field conditions and as a result, extraction efficiency averaged only 31%. The low extraction efficiency was further exacerbated by cold weather conditions, which made it difficult to maintain the shea paste at the required temperature. In order to improve extraction efficiency, the technology would have to incorporate a heating device to maintain paste at an optimum temperature. This is particularly important during cold weather.

6. Recommendations

1. Examine alternative small-scale shea processing technologies, primarily in terms of their technical efficiency. These include the hydraulic press which is commonly used for palm oil extraction, and further studies on the continuous screw expeller which were started at TCC. An extraction efficiency of between 40% and 45% (as opposed to the 31% obtained with the bridge press) would probably make small-scale shea processing marginally profitable at current international prices.

2. Research shea nut harvesting, handling and storage practices in order to improve the quality of butter produced. This would form a component of the support facility for the large scale processing of shea butter. Improving nut quality would be

of direct benefit to the traders and intermediaries who will be commissioned to supply large scale processors with high quality nuts.

3. Study butter shelf life to ascertain the critical points at which deterioration occurs and how it can be most effectively prevented. This is a second component of the support facility for large scale shea processing, and seeks to inform the selection of environmentally sustainable handling and processing practices which do not rely on the use of firewood.

4. Review the profitability of small-scale shea butter extraction once the effects of recent exchange rate adjustments have been fully felt.

References

Bosuner, A. (1998). Market analysis of shea butter in Ghana. Study commissioned from Mrs. A. Bosuner, project consultant.

Collinson, C. (1999). International market analysis for shea butter. NRI report No. 2403

Donkor, P. (1999). Testing of shea butter equipment. Study commissioned from the Technology Consultancy Centre, Kumasi.

Ellis, W. (2000). Quality analysis of shea butter. Study commissioned from the Biochemistry Department, UST, Kumasi.

Gray, A. (1997). Socio-economic investigation of improved processing of shea nuts in northern Ghana. ODA Report R6631.

Stringfellow, R.,J.Coulter, T. Lucey, C. Mckone, Ambereene Hussain (1996). The Provision of Agricultural Services Through Self-Help in Sub-Saharan Africa. Natural Resources Institute and the Plunkett Foundation.

Swetman, T., Hammond, L. and Gray, A. (1997). Improved processing of shea nuts in northern Ghana. Final technical report R6631.

Appendix 1. Terms of reference

Assess whether the bridge press technology can make small-scale shea butter processing profitable. The assessment includes:

- Identification of organisational features of a small-scale shea butter processing business that affect returns from processing. These include level of output, labour productivity, management structures, and seasonal fluctuations in shea nut price.

- Examination of a variety of technologies and processing practices for their cost effectiveness and efficiency.

- Analysis of quality and shelf life of butter produced by various technologies and processing practices.

- Investigation of marketing outlets and strategies which will enable small scale processors to maximise returns from processing. These include linkages between processors, NGOs and exporters to enable processors to access working capital and export markets.

Appendix 2. Methodology

Organisation of shea butter processing business

Location

A small-scale shea butter processing pilot was initiated at two villages, Kanfiehiyili and Chanzegu, located some 25 km from Tamale in Northern region. The villages were chosen on account of their previous participation in the shea butter processing trials conducted by NRI, TCC and ITTU, in which the bridge press technology was appraised.

Fixed and working capital

Processing equipment for the pilot was commissioned from Tamale ITTU by TechnoServe. TNS also provided the structure at the processing site for housing the equipment. TNS also procured 320 bags (26.9 MT) of shea kernels for processing. The initial 200 bags were procured through a dealer in Tamale and transported to the village. The purchases were made in May (before the start of the shea harvesting season) and the kernels obtained had been stored from the previous season. They were therefore expensive (55,000 cedis per bag) and of indifferent quality, due presumably to poor post-harvest handling and storage techniques. However, with the onset of the shea harvesting season, the remaining 120 bags (of freshly harvested kernels) were purchased directly from the women who were involved in the pilot at 35,000 cedis per bag.

Management of processing business

A group of women from each village volunteered to participate in the pilot. On the advice of TNS, a management body was set up, comprising three women from each village. The management body was responsible for selecting women and forming them into groups which ran the processing shifts. TNS also assisted the women to write a constitution to ensure good management practices. The management body took charge of addressing disputes between individual members and groups. A male secretary was elected to the Kanfiehiyili group and received training in bookkeeping. This individual was the only literate person in the community, and was appointed to the post of secretary on account of his literacy. He was responsible for recording daily income and expenses incurred and keeping an inventory of stock. Women conducted most of the processing work, but a man from Kanfiehiyili was employed to operate the corn mill. The women had not received training in operating the mill and lacked confidence in handling the machinery. Culturally, milling is regarded as man's work.

Although women from both villages participated in the pilot, all the equipment was sited at Kanfiehiyili, as it was impractical to divide it between the two villages. Neither was it feasible, for security reasons, to site it half way between the two settlements. The women from Chanzegu therefore had restricted access to the processing centre, as they had to walk a distance of some 1.5 km to reach the site.

Most of the women claimed to be familiar with the technology, due to their involvement in the earlier NRI project. However, Mr. Peter Donkor from TCC provided the women with a two day "refresher course" on the use of the equipment and the processing methodology prior to the start of the pilot.

A technical officer from MoFA supervised the processing operations on a day to day basis. He assisted the women in sorting out problems and ensuring that production continued smoothly, advised on repair and maintenance of equipment, and kept detailed records of production, expenditure, stoppages and attendance by individual group members.

TNS staff kept an overview of the pilot, advised the women on management structures and assessed the entrepreneurial spirit of the groups. He also collected data concerning the economic performance of the pilot, which was used in the financial analysis of the operation. A staff of MoFA collected weekly price data of shea kernels sold at Tamale market between May 1999 and February 2000.

An agreement was signed between TNS and the women, defining the roles and responsibilities of each party. The equipment was a loan from TNS, which reserved the right to reclaim it at the end of the pilot, subject to the women's performance. If TNS is satisfied that the performance of the group is sufficiently entrepreneurial, the group will have the opportunity to purchase the equipment on a loan repayment basis. The pilot was run as a processing service centre, with a fee of 8,000 cedis per bag of shea kernels processed being paid by TNS to the groups.

The women agreed to process every day with the exception of market days, which are held every sixth day. Ten groups were formed, six from Kanfichiyili and four from Chanzegu. Each group was made up of six members. Thus a total of 60 women were involved in the pilot. The groups worked a shift system, with two groups working each shift (i.e. one day). This meant that each group were supposed to work once every six days. The shift began at approximately 9 a.m. and continued until dark. Butter was packaged at the production site and transported to Tamale for storage.

Marketing of shea butter

TechnoServe took responsibility for marketing butter produced by the pilot and undertook to pay the women a fixed processing fee. This was done to cushion the groups against the risks of selling to a European market which had been unusually depressed during 1999.

<u>On-Station Technical Assessment of Processing Technology</u>

Technical trials at the TCC were run concurrently with the processing pilot. The objective of the trials was to assess a variety of technologies and processing practices in terms of their technical efficiency and product quality for small-scale shea butter production. The trials were also undertaken in order to dispel local misconceptions (documented by Bosuner, 1998) surrounding the efficiency of the bridge press technology and in particular, the quality of its product.

<u>Optimisation of processing parameters and equipment</u>

Preliminary trials were conducted on unroasted kernels to optimise extraction parameters (shea paste moisture and temperature) for maximum extraction efficiency. Using the optimised parameters, a series of extraction trials was conducted to identify the most efficient combination of equipment in terms of extraction efficiency and quality of butter.

The following equipment combinations were used in the trials:
crusher powered by an 8 HP diesel engine
corn mill powered by an 8 HP diesel engine
wet-type grinder powered by a 3.5 HP petrol engine
[1]TCC bridge press with straight piston, cage diameter 30 cm
[1]MoFA bridge press with straight piston, cage diameter 32 cm
[2]bridge press with tapered piston (designed for palm fruit oil extraction)
[3]small-scale continuous screw expeller

The crusher and corn-mill were commissioned from SIS Engineering, Kumasi by TNS. The TCC press and screw expeller belong to TCC, and the other two presses and wet-type grinder were borrowed from MoFA.

Table A1. Equipment combinations used for shea butter extraction

Crushing	Milling	Pressing
Crusher	Corn mill	TCC press
Crusher	Corn mill	MoFA press
Corn mill	Corn mill	TCC press
Corn mill	Corn mill	MoFA press
Crusher	Wet-type grinder	TCC press
Crusher	Wet-type grinder	MoFA press
Corn mill	Wet-type grinder	TCC press
Corn mill	Wet-type grinder	MoFA press

[1]The press used by TCC in earlier studies has a cage diameter of 30 cm. MoFA have introduced a similar press with a larger capacity (32 cm diameter cage). However, the efficiency of the MoFA press in relation to the TCC press has not been established.
[2]The tapered piston press was abandoned early on in the trial as it was found unsuitable for the extraction method used.
[3]Crushed and whole kernels were also passed through the screw expeller.

Once the optimum combination of equipment had been identified, further trials were conducted to compare the extraction efficiency and quality of butter produced from roasted and unroasted kernels and from old (last season's) and new kernels. Roasting of kernels was carried out in an open aluminium pan mounted in a TCC designed oven. Kernels were roasted in 5 kg batches. New kernels were roasted for an average of 28 minutes at 112oC and old kernels for 17 minutes at 100oC. Butter quality was assessed in terms of moisture, free fatty acid content and extraneous matter. A more detailed quality analysis was conducted in the Department of Biochemistry of the University of Science and Technology, Kumasi. In addition to moisture, FFA and extraneous matter, colour, viscosity, Kreis test (Rancidity index) and peroxide value were measured. A sensory panel was also set up to obtain consumer reaction to the various butters.

Appendix 3. Principal Equipment Failures

Diesel engine
The pulley of the diesel engine broke and had to be taken to Tamale for welding. It took persistent calls on ITTU management, from both the MoFA monitor and the TNS office in Tamale, before after sales servicing of the diesel engine was carried out.

Crusher
The pulley required repair work at ITTU. The discharge chute of the crusher had to be modified as it scatters crushed kernel pieces far beyond the collecting bowl due to its design. The two bearings on the shaft broke and had to be replaced. The metal sieve in the crusher was damaged and had to be welded. Spare metal sieves also had to be purchased.

Corn mill
Grinding plates were sharpened on a fortnightly basis. Bolts and nuts holding the grinding plates were broken and replaced. Two pairs of spare grinding plates were purchased. The mill operator claimed that the chamber of the mill was not properly designed. The product stuck inside the chamber, which had to be opened to remove the blockage. Opening was also difficult, as all the nuts and bolts had first to be loosened. Other mills have simpler opening mechanisms such as a hook, which can be opened and closed quickly and easily.

Presses
Three presses were used for the pilot. The cross and side bars of the TCC press buckled and were repaired by a local fabricator. The concrete platform holding the press cracked and had to be reconstructed. The cross bar of the ITTU press split and was welded. An additional press plate was installed. The pressure plate of the combination press was replaced. The spindle was also replaced, an extra pressing plate installed and cross bars reinforced by welding.

Appendix 4. Financial Assumptions and Workings

Capital cost budget

Assumed real weighted cost of capital	20% per annum		
Fixed capital costs	USD$	Years	Annualised cost
Diesel engine 8HP	1,021	5	341
Crusher	437	5	146
Mill	617	5	206
Bridge presses	1,460	5	488
Building	800	10	191
Tools and other durable equipment	130	10	31
Total	4,465		1,404

Working capital costs:	
Non raw material (NRM) annual operating costs	11,453
No of months NRM operating costs required	0.5
Raw material annual operating costs	23,468
Mean raw material storage period (months)	5.8
Working capital required ($)	12,232
Annual cost of working capital ($)	2,344
Total capital investment ($)	16,697
Total annualised capital cost ($)	3,748

Output budget:

Machine capacity (tonnes nuts/hour)	0.025
Number of bridge presses	4
Operating hours per day	6.0
Operating days per month	21.7
Operating months per year	11.5
Annual shea nut requirement (tonnes)	149.5
Yield dry/raw	0.31
Annual output of shea butter (tonnes)	46.3

Raw material budget:

Annual shea nut requirement (tonnes)	149.5
Cost of shea nuts - $ per tonne	152
Annual raw material budget ($)	22,720

Revenue budget:

Annual output of shea butter (tonnes)	46.3
Revenue per tonne ($)	600
Total annual revenue ($)	27,807

Labour budget:

Type of labour	Persons/ machine	Cost/man-month	Months worked	Number of machines	Cost
mill operator	1	35	11.5	1	402.5
Press operator	4	35	11.5	4	6440
Total cost per annum					6842.5

Fuel budget:

Fuel consumption/tonne nuts (litres)	12
Cost of fuel per litre	0.47
Total cost per annum	843

Analysis of profitability	**$**	$ per annum	$ per tonne of product	% of revenue
Operating costs - variable:				
Raw material	152 per tonne	22,720	490.24	82%
Transport of nuts to processing site	5 per tonne	747	16.13	3%
Fuel		843	18.19	3%
Miscellaneous processing materials	19 per tonne	2,840	61.29	10%
Direct labour		6,843	147.64	25%
Packaging of butter	15 per tonne	695	15.00	3%
Transport of butter to exporter's depot	5 per tonne	232	5.00	1%
Sub-total variable costs		**34,921**	**753.50**	**126%**
Operating costs - fixed:				
Management ($200/month)		2,400	51.79	9%
Annual processing site rent		20	0.43	0%
Storage facilities	20 per month	230	4.96	1%
Maintenance of machines	30 per month	345	7.44	1%
Sub-total fixed costs		**2,995**	**64.62**	**11%**
Sub-total operating costs		**37,916**	**818.12**	**136%**
Contingency - 5%		1,896	40.91	7%
Total operating costs		**39,812**	**859.03**	**143%**
Capital costs		**3,748**	**80.88**	**13%**
Total annual costs		**43,560**	**939.91**	**157%**
Annual revenue		**27,807**	**600.00**	**100%**
Profit (loss) before tax		**-15753**	**- 339.91**	

Appendix 4. On-Station Technical Assessment of Processing Technology

The technical findings are described in detail in "Testing of Shea Butter Equipment", a study report commissioned by this project from the TCC. A further study which analysed samples for quality characteristics and shelf-life was commissioned from the Biochemistry Department, UST, Kumasi. The main findings are summarised below.

Optimisation of oil extraction efficiency

Extraction parameters (paste temperature and moisture) to optimise oil extraction efficiency (OEE) were investigated. A series of trials at paste moisture levels of 10, 12, 15, 18 and 20% and temperatures of 50, 55, 60 and 65°C was conducted (Tables 3 and 4). Highest extraction efficiencies were obtained at a paste temperature of 60oC, with a paste moisture content of 12% and 15% for the TCC and MoFA presses respectively. Highest extraction efficiencies achieved were 68.5% with the TCC press and 70.8% with the MoFA press. (The OEE is the percentage of the total oil extracted from the kernel. Average oil content of the kernels sampled was 54.3% and the OEE is therefore equivalent to a butter yield (as a percentage of kernel weight) of 37.0% and 38.2% for TCC and MoFA presses respectively).

Table A2. Average Oil Extraction Efficiency (OEE) of the MoFA press at different temperature and moisture combinations using unroasted old kernels

	[a]10%	[a]12%	[a]15%	[a]18%	[a]20%
[b]50°C	59.3	65.1	67.1	67.8	62.0
[b]55°C	61.8	64.5	70.8	62.2	59.8
[b]60°C	61.0	68.8	69.0	64.2	62.7
[b]65°C	59.8	63.5	71.0	-	-

[a]paste moisture content
[b]paste temperature

Table A3. Average Oil Extraction Efficiency (OEE) of the TCC press at different temperature and moisture combinations using unroasted old kernels

	10%	**12%**	**15%**	**18%**	**20%**
50°C	59.3	56.5	64.1	59.9	60.3
55°C	64.1	64.6	65.1	60.4	57.5
60°C	62.1	68.5	66.9	60.1	56.8
65°C	61.7	66.5	65.6	-	-

[a]paste moisture content
[b]paste temperature

These results support the theory that lower pressure presses are more efficient with higher moisture pastes. The TCC press has a smaller piston diameter (30 cm) than the MoFA press (32 cm) and therefore generate a higher pressure for the same force applied. The TCC press will therefore be more efficient on pastes with a lower moisture content (12%) than that required for the MoFA press (15%).

The initial optimisation of paste moisture and temperature described above was carried out on unroasted kernels. However, trials were subsequently conducted on roasted kernels to ascertain whether roasting has an effect on oil extraction efficiency. Results are reported in Table 5. Unroasted kernels were found to have a higher OEE than roasted kernels (68.5% against 63.9%), but the reason behind this difference is not clear.

Table A4. Average OEE at a paste temperature of 60oC using roasted and unroasted new kernels

Press type	Paste moisture	Roasted kernel	Unroasted kernel
TCC press	12%	65.3%	67.8%
MoFA press	15%	62.4%	69.2%

A higher average oil extraction efficiency was obtained from old kernels (69.7%) than from new ones (62.6%). Results are reported in Table 6. This is to be expected, as the moisture content of new kernels is higher than that of old ones and bears out the reluctance of large scale commercial processors to purchase new kernels at the beginning of the harvesting season, before they have thoroughly dried out.

Table A5. Average OEE for new and old roasted kernels

Press type	Paste moisture	Paste temperature	New roasted kernels	Old roasted kernels
TCC	12%	60°C	62.8%	68.5%
MoFA	15%	55°C	62.4%	70.8%

The wet-type grinder was tested for milling crushed shea kernels. It produced higher temperatures and a finer particle size paste than the corn-mill. However, its extremely limited throughput made it unsuitable for processing. Comparable milling rates were achieved by opening the grinder plates (i.e. reducing plate pressure) to allow a faster throughput, but this gave rise to lower temperatures and a coarser paste and resulted in a poor oil extraction efficiency. Results of particle size analysis on cake samples reveal a correlation between oil extraction efficiency and particle size (fineness) of the paste to be pressed (Table 7). It is therefore important to ensure that kernels are finely milled in order to enhance oil extraction.

The MoFA press with the tapered piston and cage had to be abandoned after only two trials because its design was found to be unsuitable for the extraction process. The shea paste was put into small cotton bags prior to pressing but the tapering nature of the piston put non-uniform pressure distribution on the bags. This resulted in lower oil yield and increased number of broken press bags. This type of press is normally used for palm oil extraction.

Table A6. Effect of paste fineness on oil extraction efficiency

Sample	Percentage of cake passing through a 710 um sieve	Percentage OEE
1	23.1	49.2
2	34.8	54.1
3	38.1	61.6
4	39.8	65.1
5	42.7	68.9

Initial problems were also encountered with the straight sided MoFA press. The bridge arrangement was poorly designed and had to be corrected at the SIS Engineering workshop, Kumasi.

The mechanical crusher, purchased from SIS Engineering also gave some problems. The roof of the crushing chamber was low and resulted in the finer pasty portion of the crushed kernel sticking to the chamber roof and periodically jamming the crusher. The problem was corrected at SIS by raising the roof.

Mini expeller trials

The use of a small-scale continuous screw expeller for the extraction of shea butter was investigated. Trials were conducted using roasted and unroasted kernels at moisture levels of 4% and 6%.

The temperature required in the extraction chamber of the screw expeller in order to extract shea oil should be 80°C or above. In commercial expellers, this temperature is made possible by heating the crushed kernel with pressurised steam before material drops into the extraction chamber of the expeller.

To help attain higher temperatures (above 80°C) in the extraction chamber, crushed kernels were mixed with crushed palm kernel cake in various ratios and the mixture run through the expeller for 90 minutes. The objective of adding palm kernels was to increase friction and thus generate heat in the chamber, but this proved unsuccessful. The shea/palm kernel mixture only resulted in the jamming of the expeller worm in the chamber.

In the first set of trials carried out using crushed and roasted shea kernels mixed with spent palm kernel cake, only an oily paste (instead of clear oil) was expelled. The highest temperature achieved in the extraction chamber during the trials was 55°C, which is well below the required temperature. However, there was a marked improvement in the performance of the expeller with whole unroasted kernels, after heating the extraction chamber for 30 minutes with a charcoal pot fire. An average oil extraction efficiency of 9.3% was obtained.

Quality characteristics of shea butter

Twenty butter samples processed under different experimental conditions were analysed for moisture content. The values were generally low, ranging between 0.07% and 0.78%. All but four samples had moisture levels below 0.50%. Roasting of kernels had a significant effect in reducing the moisture content of the extracted oil (Table 8), presumably by lowering the moisture content of the kernel. Moisture content of the butter is an important component in assessing quality since it has an impact on fat hydrolysis and storage life.

Table A7. Moisture content of butter processed from roasted and unroasted new kernels

Press type	Paste moisture	Moisture content of roasted new Kernels	Moisture content of unroasted new kernels
TCC	12%	0.11%	0.26%
MoFA	15%	0.22%	0.38%

The moisture content of extracted oil was found to increase with increasing moisture level of the paste at pressing. As paste moisture increased from 10% to 20%, moisture content of extracted oil increased from 0.12% to 0.61% (Table 9).

Table A8. Moisture content of butter processed from pastes of different moistures at 55oC

Percentage paste moisture	Percentage moisture content of butter
10	0.12
12	0.14
15	0.26
18	0.48
20	0.61

Free fatty acid levels of the 20 samples analysed ranged between 0.51% and 1.75%. Oil from old kernels had significantly higher levels of free fatty acids than oil from new kernels. This was observed for both roasted and unroasted kernels. However, roasting did appear to have an inhibitory effect on free fatty acid formation in new kernels. Free fatty acid levels in oil extracted from roasted new kernels were significantly lower than those from unroasted new kernels, as shown in Table 10.

No significant difference was found between levels of extraneous matter in oils extracted at paste moistures of 10% and 12%. But at 15%, extraneous matter increased, especially when the kernels were roasted before milling (Table 11). This phenomenon was physically observed during the trials. Oils obtained using 10% and 12% moisture pastes were cleaner, with lower levels of suspended particles, than those extracted at moistures of 15% and above.

Table A9. Free fatty acid content of butter processed from roasted and unroasted, old and new kernels

	Roasted kernels	Unroasted kernels
New kernels	0.88%	1.87%
Old kernels	2.41%	2.49%

Table A10. Effect of paste moisture on extraneous matter in butter processed from new kernels

Kernel type	Paste moisture	Extraneous matter in butter
Unroasted	10%	14.0%
Unroasted	12%	14.2%
Unroasted	15%	18.9%
Roasted	15%	20.3%

A relationship was observed between paste moisture at pressing and number of press bags broken per extraction trial. Broken bags result in contamination of oil and high levels of extraneous matter. More bags were broken during pressing at 15% paste moisture than at 12%. Roasting also appeared to increase the breakage of bags. The reason behind this is not clear.