Shea Butter Manually Operated Mixer

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Shea butter is becoming internationally known as a skin care product used for moisturizing and other home applications. Women in Mali, North Africa, lack the efficient tools and education to develop a better means of producing shea butter products. The current process is physically exhausting and time demanding, taking several hours to complete. An engineering design team was established in 2004/2005 to develop a better means of the mixing process, utilizing a manually operated machine. After thoroughly researching, designing and experimenting, a prototype was developed, which optimized the mixing process. Four years after the initial implementation of the machine, a research team went back to investigate the project. Upon their findings they identified several areas where the mixer could be improved. A second senior design team was established in 2009/2010 to continue with a redesign of the machine. In order to help African women establish fair-trade Shea Yeleen International, a non-profit organization, was founded. It is the hope through the success of the redesign that Shea Yeleen International will be able to disseminate the machine and help fight poverty in Africa.

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Mali's Economics

Mali's gross domestic product (GDP) per person in 2006 was estimated at $470 US, placing it among the world's top 10 poorest nations[1]. However, this data is not an accurate representation of the distribution of wealth. Less than 30% of the population is above this estimate, 36% of its population is below the poverty line, and unemployment was at 30% in 2004[2]. The need for economic freedom is essential to empowering this impoverished nation.

One way to help fight poverty is utilizing Mali's renewable resource, shea butter. It is estimated that a rural woman can earn as much as 10% of their annual income just through the sales of shea butter[3]. Locally, shea butter is derived through a labor intensive process by which oil is extracted from the shea nut. Traditionally the process to produce shea butter is done by hand taking eight to ten hours per women to process ten kilograms of shea nuts[4]. Exploring the most labor intensive step within the process, it was identified that the mixing/kneading process would increase yields, save time, and reduce effort.

2004/2005 Design Team

A design team was assembled in the 2004/2005 academic year at the University of St. Thomas in St. Paul, Minnesota. The team consisted of three students set out to identify a need in the impoverished area of Northern Africa. That need was for the ability to produce shea butter at the local level and distribute the goods internationally.

Identifying the process steps involved with shea butter production the team found mixing the paste with water to extract the oil the most labor intensive and time consuming process. The method of mixing is done by hand, and most often the container holding the paste is placed on the ground. Women stand over the bucket bent at the waist causing strain on the back and making the process only suitable for younger women. Addressing this problem, the team set out to identify key customer requirements along with meeting engineering specifications. Some of the requirements are as follows:

- Intended user set for Mali women, North Africa
- Targeted cost less than $100 US, with affordable locally available parts
- Fabrication and maintenance reasonably simple for local Malian machine shop: cutting, welding, etc.
- Simple, minimal moving parts, easy to clean, and safe (non-toxic, no sharp edges or exposed parts)
- Easy to access shea paste for addition and removal
- Durable to withstand climate of Mali and up to 5 years of use
- Manually powered but with less physical effort than current method
- Improve oil extraction to increase yields

In addition, groups of Malian women will form cooperatives where they can have access to the mixing machine. The machine shall produce enough shea butter products for personal consumption and to sell in local and international markets, thus providing an opportunity to earn a steady source of income.

This project should have a positive impact economically and financially on the people of Mali. There will be culturally appropriate training materials in French and Malian languages supplied with the final design. Illustrations will accompany the training materials to show operation techniques. The final design will be sent to local Shea Yeleen International contacts to continue implementation of the machine.

Strategy and Thought Process

Using an engineering approach to problem solving, customer requirements were identified and aligned to engineering concepts and key metrics. The customer requirements and how they align to engineering practices include:

- Safety → no sharp edges exposed, minimal exposed moving parts
- Easy to Use → easy to clean parts, open container for access, no complex setup or power systems
- Simple design → fabrication reasonable for local Malian
- Cost effective → less than $100 to produce
- Non-corrosive → materials made from plastics, stainless steel, and composites

Identifying these key requirements allowed for focus when building prototypes. In order to ensure an efficient development of all aspects of the project the mixer was separated into three main components: blades, container, and power source/transmission.

Each one of the components were researched, tested, and proven out before a final selection was made. The blade selection was the most critical feature and needed to imitate the hand mixing motion to extract the oil. The container needed to be locally available and easy to clean. The power source and transmission had to have components that were locally available and able to fix by a local craftsman.

Through several design iterations, testing, and data collection, a final design was produced yielding success. Key objectives obtained were:

- The mixer met the requirement cost of approximately $50.00 (in Mali).
- All parts in contact with shea paste are made of stainless steel or plastic.
- Disassembly is easy because it requires no tools
- Wing nuts can be unscrewed allowing clamps to be removed easily
- Shaft and shaft post are removed in one piece separating easily from bucket. This allows for the easy cleaning of the mixer
- The mixer can accommodate many different sized containers. The use of a wide container allows for easy access to the paste
- Rotating the crank at approximately 60 rpm causes oil extraction at approximately 30 minutes
- Oil extraction ratio of 3:1 was maintained using the mixer
- Operation of the mixer can be done by one woman.
- There is an option of sitting or standing while using the machine
- Tensioning the belt only requires the turning of a wing nut

The final design for the project met the customer requirements and yielded consistent results. The final design is depicted in the Figure 1.

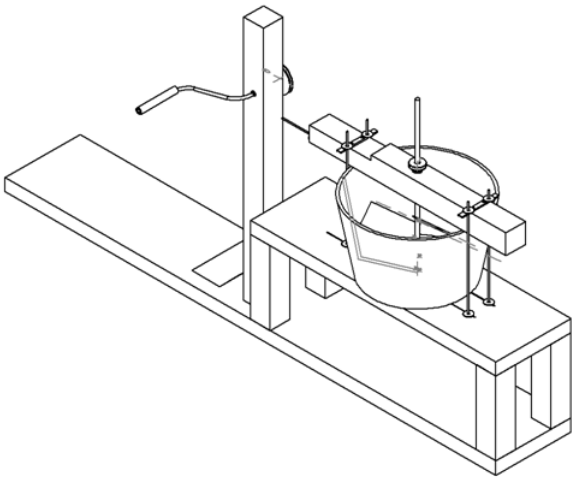

Figure 1 – Original Design

Communication, Communication, Communication

The design team was fortunate to have had several local contacts from Mali while working on the project. A local consultant gave firsthand experience with living in Mali, along with working with Shea Yeleen. This proved critical in understanding cultural differences, social norms, and the environment which the machine was to be implemented.

Several issues arose when working with an international customer. The primary issues were mostly cultural differences: time was not measured by the clock but by when people showed up; making shea butter was only done by women, the team was fortunate have at

least one of its members represented. Additionally, coordinating phone calls and travel arrangements took extra effort to overcome language differences and time zones. Safety was emphasized but was little of issue when onsite.

What was truly inspiring was witnessing the relationships build between two very different worlds. Regardless of where you are in this world, there are fundamental principles among all cultures and nations: the sense of right and wrong, the knowledge that you are part of something greater than yourself, and the gift of relationships. It is the building of relationships that bind us together. They are built on trust, honesty, and open communication. One example was with a member explaining how the machine worked not with words but with actions. To hear, see, and witness the local Malians except him and show they understood gave a great sense satisfaction and honor to be part of something greater than anyone of us.

2004/2005 Success and Implementation

After extensive research, several prototype iterations, and testing, the Mali Mixer team was able to develop and implement a successful prototype. Using feedback from the Malian women was vital for the final design. User comfort was crucial for ease of use, range of motion, and the location of the power source. The manually powered machine met all customer and engineering design requirements. Using the mixer, the women in Mali were able to produce twice as much shea butter with little physical strain. The final design was able to extract oil in little as 30 minutes, greatly reducing the average mixing time. With reduced mixing time, less physical strain and an increase in batch size, the production of shea butter greatly increased.

Shea Yeleen International (SYI) will be able to distribute the machine, educate the local women on how to form cooperatives, establish fair-trade, and how to build, maintain, and optimize production with the machine. With the increase of shea butter production in the villages, women will be able to sell their products and generate additional income for themselves. As SYI begins working with more women in Mali, the establishment of fair-trade and the fight against poverty will be set in motion.

The Mali Mixer…Four Years Later

Four years after the initial implementation of the machine, a research team went back to investigate the project's success. Upon reviewing the shea mixer in Mali, several observations were made that prompted the need for a re-design. Multiple problems that presented opportunities for future improvements were:

1. Blades sometimes get stuck on the sides of the bucket during critical processing times
2. More mechanical advantage required due to the amount of torque required
3. Belt slip present due to torque, shea butter acting as lubricant, and tension less than optimized
4. Belt and tension system needs re-design. Tightening the belt caused blades to strike container, belt slip occurred frequently, tensioner buckled when tightened and more torque is required
5. Mixer is difficult to transport over great distances
6. Replace bushings with bearings to reduce friction
7. Bucket placement less than ideal, difficult to remove, and hard to position when mixing

In addition, the local users had a couple of recommendations in regards to a redesign. One of the requests was to make the machine easier to transport from village to village. The design was bulky and awkward to carry by one person. If the new prototype could be designed in such a way that one person could "cart" the machine around, it would be better utilized. They also, requested the new design to be easily operated by one individual, where current machine requires two people to operate. Overall they were generally satisfied with the first prototype. Additional questions were asked specifically about the mixer and a list of feedback was generated as shown in Figure 2.

		YES	NO	Comments
Customer Feedback	Easy to Clean	X		Was easy to clean once apart
	Cost Met	X		Would be willing to pay $200 for a mixer lasting 5yrs
	Safe to Use	X		No issues present in regards to safety and operation
	Time to Produce		X	Takes 2-3hrs to produce vs. 1.5hrs by hand
	Manufacturability	X		Local builders and materials can be found within and around Mali
	Batch Size	X		Can produce 10kg/day with machine vs. 5kg/day by hand
	Durability		X	Termite damage present on old machine

Figure 2 – User Feedback

Based on the observations and user feedback, a redesign is required to ensure the goals were met for this project. In order for the local women to be successful at producing shea butter, these issues and improvements need to be addressed and met through a design team dedicated to the success of the shea mixer.

2009/2010 Redesign Team

Based on design reviews gathered from the research team at the University of St. Thomas, the current

2009/2010 shea butter mixer team, comprised of four new team members, is working toward designing a mixer that will facilitate new customer requirements, design review feedback, and maintain the effectiveness of the previous prototype.

The 2009 fall semester was spent researching current shea mixing techniques, reverse engineering the previous mixer design, and understanding current industrial mixing methods. By the end of the semester, the shea butter team identified several conceptual designs that addressed issues from the research team and met local Malian requirements. Figure 3 shows one of the concepts that was tested.

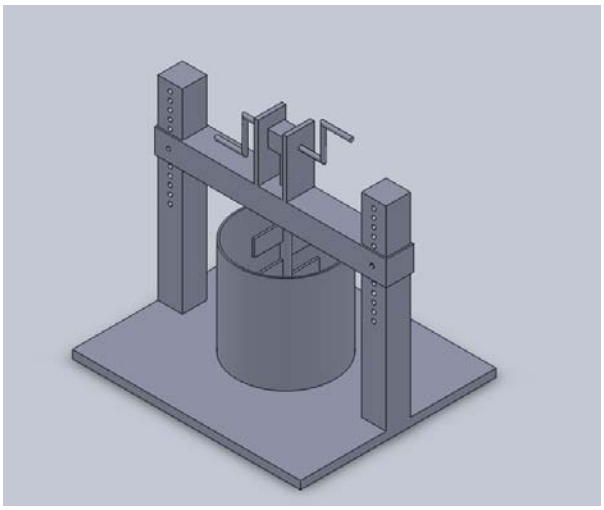

Figure 3 –New Concept

Over January the team built several different scale models of mixer designs. This allowed for testing of how quickly and easily each one produced shea butter, solved previous design issues, and satisfied the requirements set by the customer. Focus was placed on the transmission and power source along with the effectiveness in producing viable butter. The previous blade design was effective in producing shea butter; therefore, the blade concept was replicated from the previous design. Using the previous team's data for shea butter extraction, a benchmark was established for success or failure.

A control environment was constructed for testing to simulate the Malian environment. By the end of January testing and evaluation was complete and a final design was chosen to carry forth. Due to scheduling and funding issues, the team was not able to test the concept in Mali.

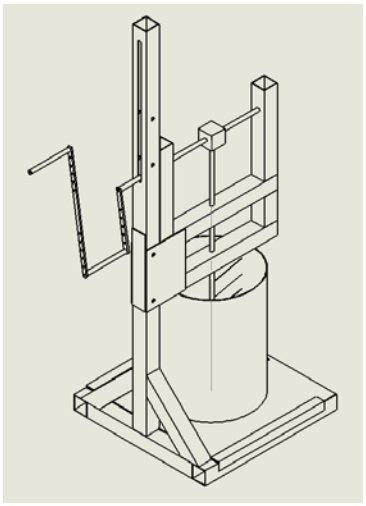

Figure 4 – Final Design

Nonetheless, a full scale prototype (Figure 4) was constructed in April. This design was tested through numerical ANSYS simulations to ensure the torque requirement on the blade shaft was sufficient, and ergonomic testing was conducted to make certain that the design was easy to use for the women in Mali. This final design will be sent to Shea Yeleen with building instructions at the end of May and then sent to Mali, where it will be fabricated from local materials.

It is the hope through the success of the mixer redesign, that Shea Yeleen International will be able to disseminate the machine and help fight poverty in Africa. With higher yields of shea butter and less strain required by the user, the feasibility of aiding women in Mali reached the goals set forth, and has the ability to empower many women upon its implementation in Mali.

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