ME 450

Final Report

Project 5 - Breadfruit Grinder

Team Foufou

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ABSTRACT

Farmers in the Cooperative KGPB (Kolaborasyon Gwoupman Peyizan O'Boy) in Borgne, Haiti have identified breadfruit as one of the most wasted agricultural products in the area because it is hard to transport, store, and preserve. One problem for Haitian farmers in Bornge is that they lack the ability to store breadfruit for later use. Breadfruit is also difficult to transport to market on the mountain goat paths, and everyone in the area harvests it at the same time, overwhelming the market. With so much breadfruit available at one time, the price drops, making transporting it not worth the effort. The goal of this project is to help the local people get through the hungry-season and make more profit by converting breadfruit into flour through several simple processes: shred, dry and grind. In flour form, it will be much easier for farmers to store and transport the product for future eating and selling. For this project, we would design and build a prototype food grinder that could be integrated with the shredding and drying systems under development by Multidisciplinary teams of students in a similar capstone course at RIT.

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Executive Summary

Many communities in Haiti are plagued by poverty and starvation. The agricultural production rate is insufficient for its population, which requires that at least half of their food sources be imported. Natives have combatted this problem by cooking with local crops, specifically breadfruit. Breadfruit spoils within 48 hours of being harvested. This severely limits its ability to provide food for the remainder of the year. Converting breadfruit into flour ensures a longer shelf life. Students at the Rochester Institute of Technology (RIT) have been working on the common three-stage breadfruit flour production process: shredding, drying, and grinding. Our task is to create the grinding portion of this process.

Our grinder prototype must meet certain specifications. In order of importance the device must: be safe for the user to operate without injury, produce breadfruit flour that is safe for consumption, produce breadfruit flour similar in consistency to typical baking flour with a particle size less than 0.1 mm, be operated by manual energy alone, be durable and capable of lasting 12 hours a day for 3 months a year over the course of 3 harvest seasons, not exceed a parts and materials cost of $400, be easily operated, be easily assembled and disassembled, be easily cleaned and maintained, weigh less than 50 lbs, and not exceed 8 cubic feet in size. This was achieved using the concept of hand operated grinding rollers. This was chosen over other designs due to being small and lightweight in nature, falling within our limited budget, and manufacturing capability given current resources. The final design consists of a set of stainless steel adjustable rollers mounted to a plastic baseplate. The baseplate contains a rectangular hole below the rollers for the breadfruit to pass through. Curved pieces of acrylic are mounted to the bottom of the plate in order to form to the top of the 5 gallon bucket and restrict movement during operation. Bolts extrude from the interior of the bucket for the strainer to rest upon. Atop the grinding mechanism is an aluminum hopper for breadfruit loading. Grinding action is achieved through the use of a hand crank mounted to the shaft of the driven roller.

The parts were purchased and designed with portability in mind and can easily fit into the bucket once disassembled. The rollers, bucket, and strainer were purchased separately while the hand crank used aluminum manufacturing processes that incorporated both mill and lathe machines. The hopper was custom designed from aluminum sheet metal and cut using a water jet cutter. These pieces were then annealed and bent to the appropriate shape. The baseplate hole was created using a mill while the acrylic form fitting pieces used a laser cutter. The final assembly was just under budget at $398. The rollers contain 5 marked gap width positions. The testing process consisted of using dried potato pieces to simulate breadfruit and determining the number of grinding passes at various gap widths that were needed to achieve a flour like consistency. It was determined that 2 to 3 passes per roller position for a total of 10 to 15 passes were necessary. Ease of assembly was tested using various groups and timed against our 20 minute threshold. A force gauge was attached to the crank handle to determine the force required to grind the breadfruit pieces. Given the handle length of 7 inches the required torque ranges from 8.75 ft*lbs to 17.5 ft*lbs depending on breadfruit size and texture.

In conclusion our breadfruit grinder prototype is easy to assemble, disassemble, maintain, and operate, but would probably benefit from being foot powered rather than hand powered. The grinding process can be difficult at times with inconsistent forces being required. Due to size, cost, and a stated preference for a hand powered device, this foot pedal concept was not applied. Better communication with the shredding and drying team would have helped clarify the size and texture of the breadfruit shreds we would have received and aided in our design process. Future cooperative projects would benefit from all parties reaching an agreement on good correspondence policies.

Problem Description and Background

Many communities in Haiti are plagued by poverty and starvation. The agricultural production rate is insufficient for its population, which requires that at least half of their food sources be imported. However, with 75% of the country making less than $2 per day, spikes in the global food market have devastating effects on the people [1]. Recent natural disasters and social unrest have proven how unstable trade can be [2].

In an effort to combat this problem, natives have begun cooking with local crops, specifically breadfruit. Breadfruit is type of tropical fig with high nutritional value [2]. This fruit is abundant in Haiti and provides a very high yield. In just 3 years, a tree begins growing fruit with one tree capable of producing 200 breadfruits at 1-2 kg each per season [4, 5]. Two breadfruit trees have the capacity to feed as many people as an acre of soybeans or potatoes [6]. It is more sustainable than most other crops due to its aversion to local insects and fungi, and the fact that farming breadfruit is as simple as climbing a tree [7, 8]. The fruit itself is rich in fiber, carbohydrates, Vitamin C, and Potassium [9].

The biggest downside of breadfruit is that it spoils within 48 hours of being harvested, which limits its ability to provide food for the remainder of the year [2]. Since an estimated 40-60% of the crop is lost due to spoiling, several outreach organizations have developed methods to convert breadfruit into flour resulting in a much longer shelf life [10]. Students at the Rochester Institute of Technology (RIT) have been working to develop a sustainable solution based on the common three-stage breadfruit flour production process: shredding, drying, and grinding [11]. Our task as engineering students at the University of Michigan is to create the latter grinding device that will ultimately produce the breadfruit flour.

With the successful completion of these devices, Haitian farmers could make flour locally and reduce the country's reliance on imports. If this flour production could be scaled up in the future, breadfruit would become a valuable export. Breadfruit flour as a gluten-free substitute for traditional flour could have a market among people with celiac disease [12].

Current Patents (Benchmarks)

Numerous devices exist with the intention of grinding breadfruit into flour. A French patent FR2668038 (A1) relates to an industrial process of converting breadfruit into flour with the intention of making cakes, fritters, spaghettis, and creams. This grinder relies on receiving thin dried strips from the skin and flesh of the fruit. Unlike the grinders that would be used in Haiti, this one relies on an electric grinder to process the dried breadfruit. This increases the shelf life of the fruit from 2 days to upwards of 2 years. [13]

Hand-Operated Food Grinder (Patent KR101462667 B1) [14]

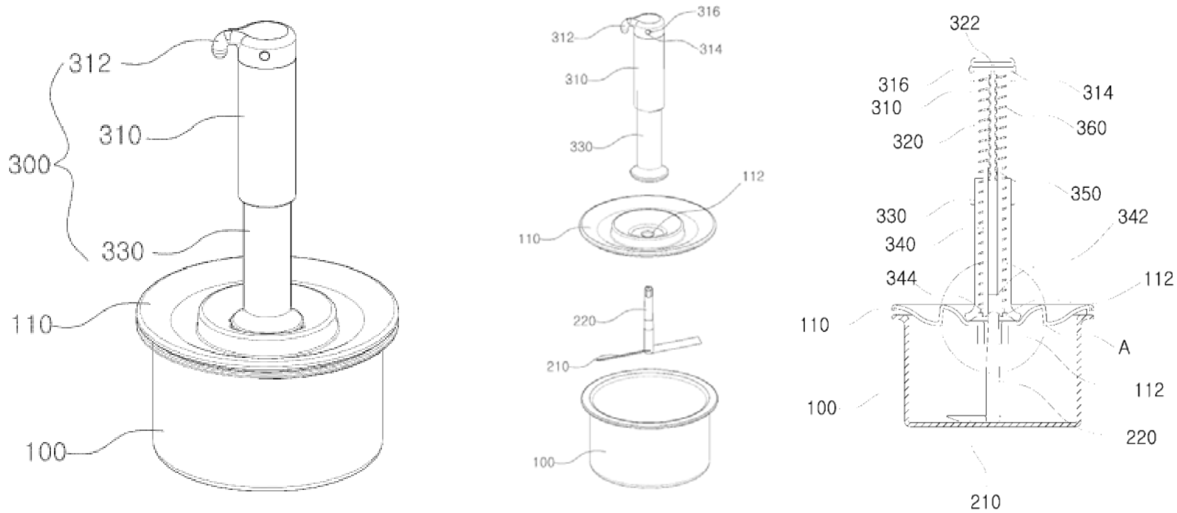


Figure 1: The patent drawing of hand-operated food grinder shows the machine’s key components. Four key parts are the handle module, lid, grinder blade, and food container. The rightmost drawing shows the cross-section of the handle module, which demonstrates the machine operation of pushing down the handlebar to rotate the blades.

This patent (KR101462667) is a food grinder that is developed specifically for environments that lack a stable source of electricity. The patent also explains that the grinder was designed to be effective outdoors with the capacity to grind hard food items such as dried beans. Simplification of assembly and ease of operation were the two main priorities when assessing the engineering specifications. The design consists of four main components—main container, lid, blades, and handle—which can be quickly assembled and disassembled for ease of transportation and storage. To operate the grinder, the user must only push down on the handle to spin the blades. The handle contains a spring-loaded, spiral-tapped, mechanism that translates downward motion of the outermost layer into rotating motion of the inner cylinder.

While the patent’s design fulfills our requirement of easy assembly and operation, it is not optimal for breadfruit flour production due to its reliance on blades. Due to limited resources in Haiti and safety concerns, we decided that using blades to grind the shredded breadfruit is not realistic. Not only do blades make cleaning and operating the machine potentially more dangerous, replacing and maintaining said parts would also be difficult after its initial implementation. The patent also fails to explain how fine the outputted granular material is, which is of utmost importance for our purposes.

Hand-Operated Vegetable Grinder (Patent KR200474849 Y1) [15]

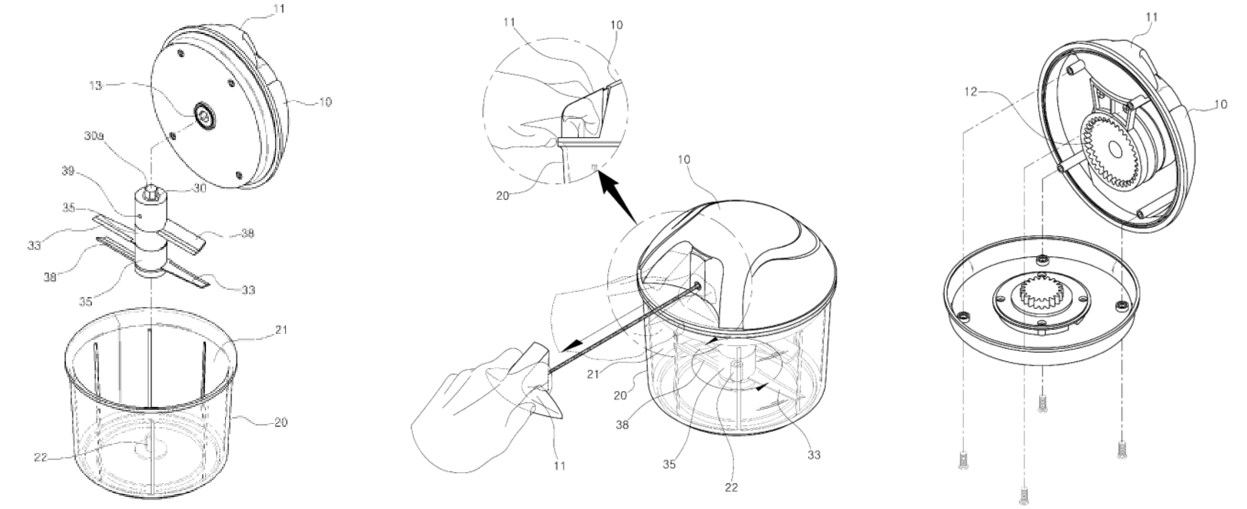


Figure 2: The leftmost drawing shows the composition of the design for the hand-operated vegetable grinder, the drawing in the middle shows its method of operation, and the rightmost drawing reveals the lid module mechanism that is responsible for generating the required rotation for grinding food. The blade module is attached to the lid module's gear, which is driven by a self-winding cable that is repeatedly pulled and wound until desired output is achieved.

This patent (KR200474849 Y1) is a hand-operated vegetable grinder developed to be used outdoors where electricity is unavailable. This grinder is extremely easy to assemble and consists of three main components: food container, blade module, and the rotating mechanism contained within the lid. This reduces the time required not only for assembly and disassembly, but also for training a user for operating the machine. An area where this patent's design falls short for our requirements is that maintenance may be required, but the built-in nature of the blade and lid modules reduces accessibility.

This designs biggest merit is its ease of operation. The machine utilizes the tension of a wound-up cable to spin the blade module in order to grind the food items being placed in the container. The intuitive nature of this pull-to-spin method will virtually eliminate any training required to operate the machine. When compared to the push-to-spin method from the previous patent or the conventional hand-cranking methods, this method seems more ergonomic and less straining for the user. This device is similar to the previous food grinder; however, this patent uses a set of blades to grind the desired food items, which is a feature we have chosen to avoid.

Compatible Technology International's Pedal-Powered Grinder [16]

Figure 3: CAD model of CTI's breadfruit grinder. The foot-pedals are geared to the grinder on the right.

Compatible Technology International (CTI) has developed a manually powered breadfruit grinder. The operator sits on the bicycle seat and pedals the mechanism to generate power. Breadfruit slices are fed into the feeder and the flour comes out of the end. This solution eliminates the need for electricity and the leg driven design allows for a greater output potential for the grinder. The seat and handles improve the comfort of the user.

This device is structurally robust, but fails to be compact. The grinder is very large and requires many parts. Compared to previous designs, this device would be more difficult to transport and assemble. The use of chains could prove to be problematic after extended use. Without the proper tools and lubricant, the design may experience mechanical failure.

Compatible Technology International's Ewing IV Grinder [17]

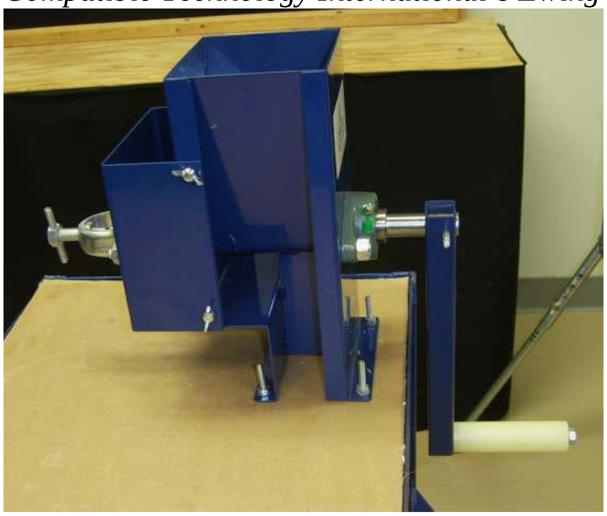


Figure 4: Assembled view of CTI's general-purpose grinder. The hand crank on the right powers the device.

Figure 5: Disassembled view of grinder shows all of the parts included in product.

CTI’s hand-powered grinder, the Ewing IV, is designed to mill maize, coffee beans, and rice. It is sold for an affordable price of $265 and disassembles quickly for ease of transport and shipping. The heat-treated burrs in the device remove the need for sharpening or replacement. While still lightweight, the metal frame provides a durable structure.

One major disadvantage of the Ewing IV is that the produce fed into the grinder must be relatively fine. This hindrance could cause the device to fail if the dried breadfruit shreds are too large. Assembly of this product leads to other issues since mounting it to a table requires a powered drill. The availability of this in villages of Haiti is uncertain. Furthermore, there are no safety features built into the design. The hopper is open and could cause injury if one’s hand is placed in there during operation.

User Requirements & Engineering Specs

Below is the list of requirements for our breadfruit grinder:

Item #	User Requirements	Importance (1-5, least to most important)	Engineering Specs
1	Produce breadfruit flour	5	Particle size < 0.1mm
			80% goes through Mesh
2	Edible and safe breadfruit flour	5	Food grade material, withstand heat and rust
3	Ensure safety for user	5	Under operation, finger cannot reach rotating parts
4	Manual energy	4	Operational with hand crank
5	Durable	4	Lifetime >= 12 hrs. /day for 3 months a year for 3 or more years
			Can be left outside without rusting for a week
6	Low cost	4	Less than $400
7	Ease of use	3	Training time under 10 minutes (assembly, disassembly, operation)
8	Easy to assemble	3	< 10 steps
			Consistent and standard nuts & bolts
			Less than 20 minutes
9	Easy to clean	3	Under 15 minutes
10	Lightweight	2	Less than 50lbs
11	Minimize size	1	Less than 2x2x2 cubic feet

1. Produce breadfruit flour [18]

Breadfruit flour production is the primary purpose of our project and comes with several very important criteria: texture, consistency, and size of particles. It should match up to the consistency of typical baking flour (approximately 0.1mm in size) according to our sponsor. Meeting this requirement relies on the use of an appropriate sized sieve with the use of Standard US Mesh 140 to ensure particles are fine enough [19]. This is a top priority and will be one of our primary design focuses.

2. Edible and safe breadfruit flour [18]

The breadfruit flour created by our grinder will need to be safe to consume and there are several guidelines for a qualifying machine.

In terms of sanitary design, all *food contact surfaces* should be: [20]

- Smooth
- Impervious
- Free of cracks and crevices
- Nonporous
- Nonabsorbent
- Non-contaminating
- Nonreactive
- Corrosion resistant
- Durable and maintenance free
- Nontoxic
- Cleanable

This is of high importance because if the grinder produces un-edible flour it is un-useable. We will need to consult with professors, online sources, and sponsors about ensuring food grade materials. There are parts that may not need to be food grade since it will not touch the flour, but anything that is in contact with food must be sanitary.

3. Ensure safety for user [18]

During operation of equipment, proper safety measures will need to be implemented in order to keep hands and feet clear of rotating equipment and prevent possible injury to the user. An unsafe machine puts the user at risk and if injury occurs the future use of the machine is in jeopardy. Safety is always of high importance when designing machines and equipment.

4. Manual Energy [18]

Manual energy will be necessary to run our grinder, as electricity is inconsistent in the parts of Haiti that our grinder will be operated. A hand crank is what we hope to implement in the design of the grinder. Comparisons between foot and hand operations were made with the conclusion that a foot pedal design while providing more energy and having a longer run time would not be feasible due to the size and cost constraints [21].

5. Durable [18]

A durable design that allows the machine to be used for many seasons is crucial. This is especially important for areas of limited resources such as Haiti. Since Haiti does not have the equipment or materials readily available to fix the machine our final design must be built correctly and with a high degree of durability. Some other qualities we hope to include are the ability for the design to last through various weather conditions and resist rust if left out in hot and humid environments.

6. Low cost [22]

Designated by the ME 450 - Design & Manufacturing III professors, the budget of our design should remain under $400. This requires a low cost design while ensuring that it will be inexpensive enough for Haitians to mimic in the future. This puts the thought of creating a cost-efficient machine for the poverty stricken country of Haiti in mind.

7. Ease of use [18]

The engineering requirement for ease of use stems from the uncertain and suboptimal environment that our machine will be operated in. As previously discussed, the limitations in transporting the equipment and communicating with the end-users are significant factors to consider in order to make our design appealing and effective. By designing an easily operated machine we plan to minimize the training time for the actual users. This eliminates the need for a 'grinder specialist' in our machines field of operation regardless of its location.

8. Easy to assemble [18]

Our sponsor, who is familiar with the field environment in Haiti, claims that tools such as hammers and screwdrivers are available in limited quantities. An accurate list of the types and quantities of tools are unlikely to be provided. Therefore, we have decided that the process of assembly needs to be simple to accommodate for limited resources. The number of steps required to fully assemble the machine will be simplified to avoid mechanical complications, and components such as nuts and bolts will be standardized to match those implemented in RIT's shredder design.

9. Easy to clean [18]

Because our design handles food, hygiene must be taken seriously. The machine needs to be easy to clean in order to avoid contamination of breadfruit flour and ensure that it remains in operable condition. In order to fulfill this requirement, the machine must be easy to disassemble, have simple construction with minimal 'hard-to-reach' obstructions, and be built to resist any non-reversible chemical wear (such as rust). We have decided that the current target time for disassembling and cleaning our machine should be approximately 15 minutes.

10. Lightweight [18]

Since the first implementation of the shredder and grinder will involve shipping the completed machines to Haiti, the sponsor recommended a grinder design whose components' net weight is under the limit set by commercial airliners (50lbs) [23]. A lightweight grinder will not only help the process of transporting it to Haiti, but also be beneficial to its implementation.

11. Minimize size [18]

Our sponsor has clarified that the grinding stage of the flour production process will not be on an industrial scale. The specific volume requirements of the end product has not been stated, but the daily grinding capacity should at minimum be 'a basketful of flour.' We acknowledge the vagueness of this standard and will proceed to establish a standard that both our sponsor and we can agree upon. In addition to the weight requirement of the machine, we have decided on a design that is optimal for tabletop operation.

Concept Generation

After breaking down the task into a flow chart, we wanted to look at a wide variety of solutions for the main function, grinding breadfruit (see Figure 6). We began by individually generating five concepts each, trying to make each design as different as possible from the rest. After sketching our designs, we passed around our drawings and individually made improvements or modifications to each other's ideas.

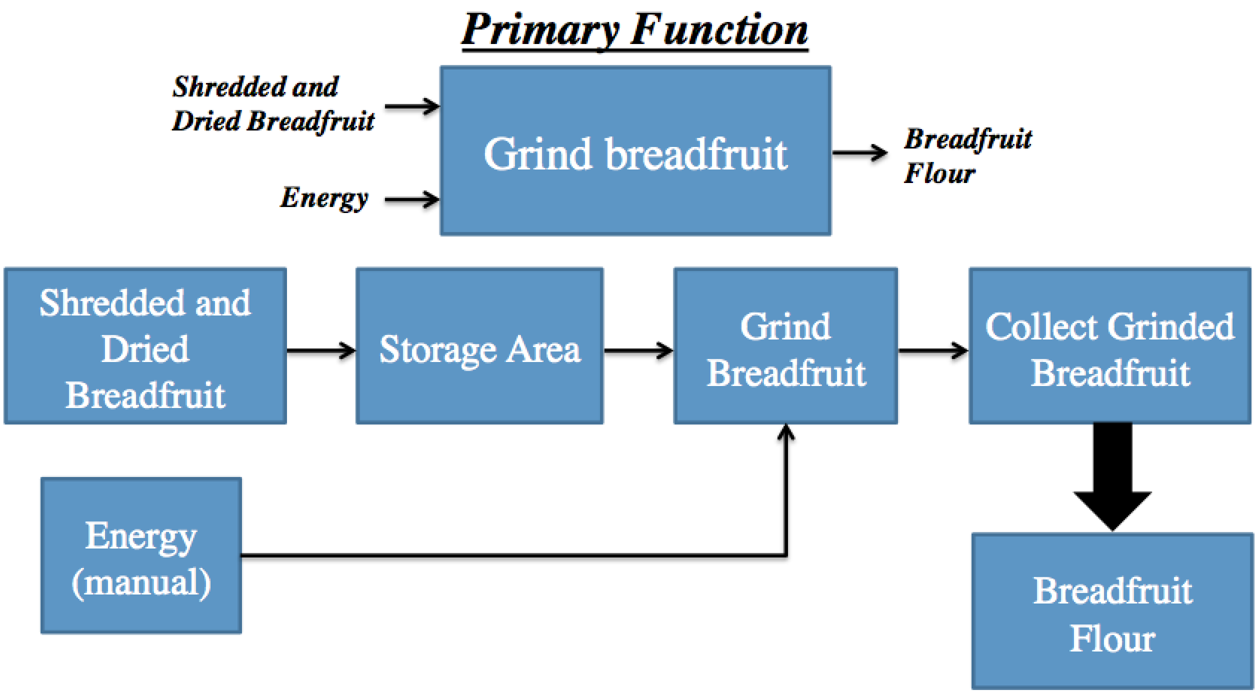


Figure 6: Functional decomposition of breadfruit grinder.

While comparing our individual concepts for grinders, we observed that there were similarities among them. Despite having twenty different designs, they were all based on one of four mechanical principles for grinding the breadfruit. Therefore, we grouped the designs into four categories of grinders: graters, rollers, blenders, and tumblers.

Graters

One way to turn the breadfruit slices into flour is to slide them along a high-friction surface, which will wear them away into a powder. A major advantage of this type of mechanism is that it uses a motion that is intuitive for many Haitians and would be easy to teach someone how to use [18]. Designs #3, #5, and #9 represent this category of grinder (see Appendix A for all sketches).

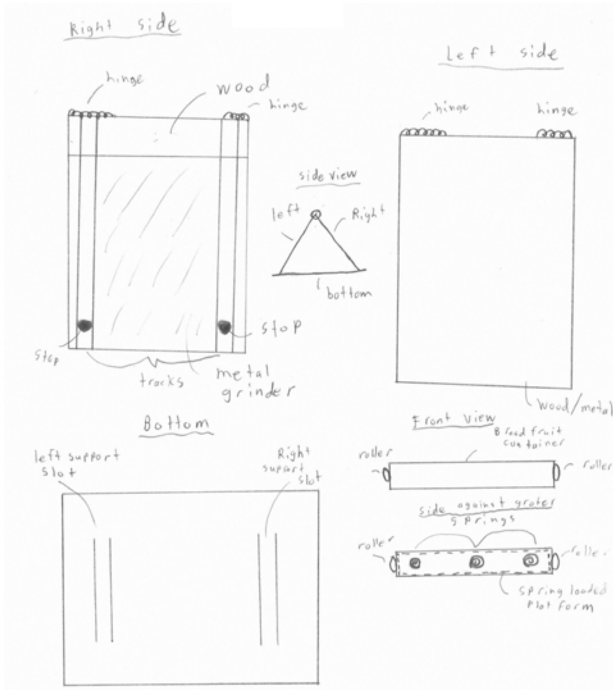


Figure 7: Design #9 consists of a collapsible grater that allows the user to slide a breadfruit carriage along a flat grating surface.

Similar in function to a cheese grater, Design #9 uses a flat grating surface to wear the breadfruit slices into a powder. The breadfruit is contained in a carriage that slides along two linear rails, much like the tracks of a garage door. The whole mechanism can collapse for easy storage or transportation.

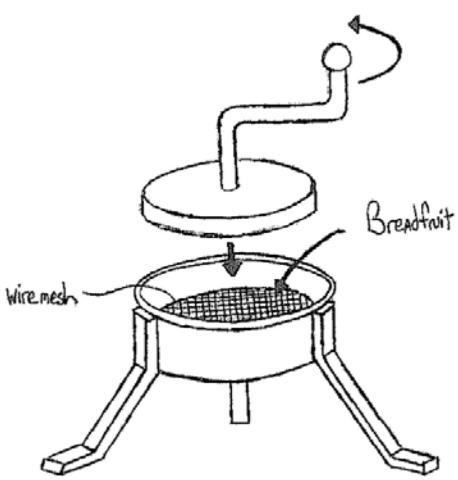


Figure 8: Design #5 is a circular grater concept that wears down breadfruit between a rotating disc and a wire mesh.

Different from the other types of graters, Design #5 uses a circular motion instead of a linear movement. The top disc is pressed down on top of the wire mesh, with the breadfruit slices in between. Rotating the handle around will create a constant planar friction that wears the breadfruit down into flour, which then falls through the mesh into a container.

Rollers

Breadfruit can also be milled into flour by mechanically crushing the slices into tiny bits of flour. The designs that make use of this method typically have one or two rotating parts that apply compressive forces and have textured surfaces. Designs #7, #13, #16, and the RIT grinder prototype are good examples of rollers (see Appendix A for all sketches).

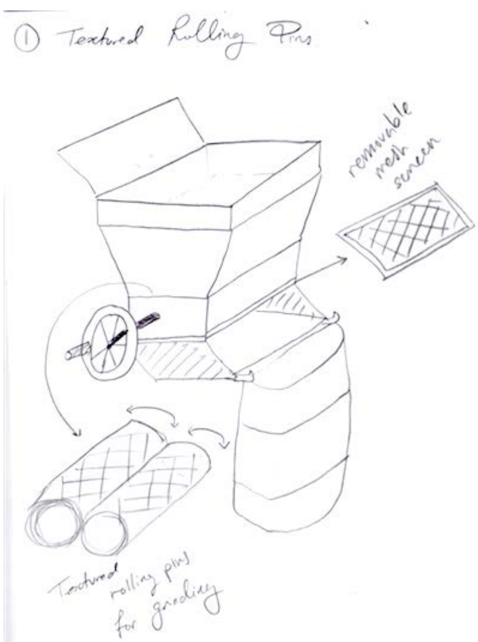


Figure 9: Design #16 uses two rotating cylinders to mill the breadfruit into flour.

Breadfruit shreds are fed into Design #16 via the hopper on top. A person cranks the grinder by hand, causing two rough-faced cylinders to rotate inward towards each other. The breadfruit is grinded by the rollers and the flour falls through the gap once it is small enough.

Blenders

Using sharp blades, blenders dice the breadfruit slices into increasingly smaller pieces, eventually resulting in flour. The blender concepts are similar in design to food processors, but make use of manual power. Designs #10, #12, and #19 represent the blender category (see Appendix A for all sketches).

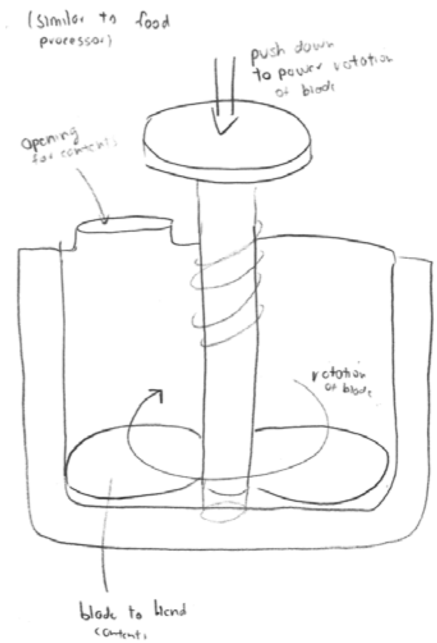


Figure 10: Design #12 grinds breadfruit via spinning blades in a container.

By slicing the breadfruit shreds repeatedly into smaller pieces, Design #12 produces flour in batches. The user will load the slices into the container, and then operate the device by manually spinning the blades. The container captures the flour and can be easily emptied.

Tumblers

Unique to the other types of grinders, the tumbler does not use direct manual force to create flour. This concept revolves around placing shreds into a sizeable container with hard objects such as stones to tumble around with. The constant interaction among the irregular surfaces will slowly wear away the breadfruit into flour. Design #7 is the only concept in the tumbler group.

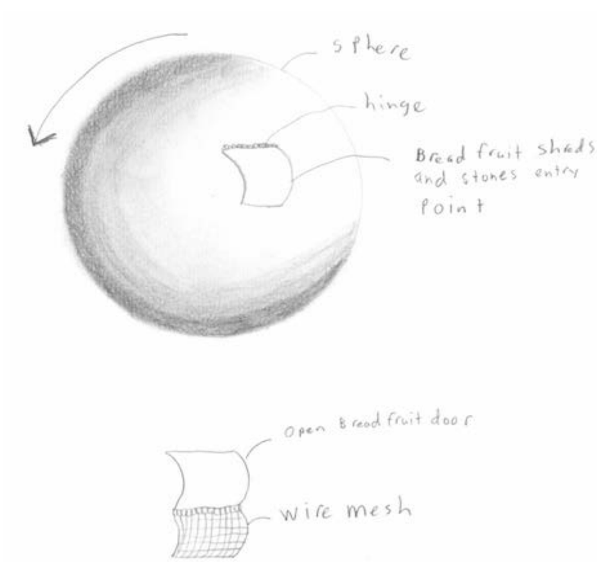


Figure 11: Design #7 grinds breadfruit by rolling it in a circular container with rocks.

Concept Selection

Using the twenty concepts generated by all four teammates, we needed to determine how to choose a final design, or designs, to work towards. To solve this problem we used a logical and objective scoring system of a Pugh chart, which incorporated requirements we are hoping to meet. Below is a Pugh chart incorporating all twenty designs drafted. We evaluated each design independently, but grouping the concepts allowed us to determine if one method of grinding was better than the rest when looking at the top choices. Refer to Appendix A for drawings of each design:

Selection Criteria/Requirements									
	Assembly & Disassembly	Durability	Ease of Manufacturing	Ease of Use	Cost	Size	Safety	**TOTAL**	**Feasibility**
Weight (1 – 3)	3	3	2	2	1	1	1		**1 – 5**
CTI Ewing IV (Baseline)	0	0	0	0	0	0	0	**0**	Not Viable - Viable
Steve's Designs									
1	-1	0	1	0	1	-1	0	**-1**	**2**
2	0	0	1	-1	0	1	1	**2**	**3**
3	0	0	1	0	1	-1	0	**2**	**4**
4	1	0	-1	1	1	0	1	**5**	**2**
5	1	0	1	-1	1	0	1	**5**	**3**
David's Designs									
6	1	0	-1	0	0	-1	1	**1**	**2**
7	0	0	0	0	-1	0	0	**-1**	**1**
8	1	0	1	-1	1	1	-1	**4**	**3**
9	1	0	1	0	1	0	0	**6**	**5**
10	1	0	0	0	0	-1	1	**3**	**3**
Jason's Designs									
11	1	0	0	0	0	0	0	**3**	**3**
12	0	-1	0	0	0	1	0	**-2**	**1**
13	0	0	0	0	0	0	-1	**-1**	**2**
14	0	0	0	0	0	0	0	**0**	**1**
15	-1	0	0	1	0	1	1	**1**	**1**
Paul's Designs									
16	-1	0	-1	0	0	-1	1	**-5**	**1**
17	1	1	-1	0	0	0	1	**5**	**3**
18	1	0	-1	1	0	0	0	**3**	**2**
19	-1	-1	-1	1	0	1	0	**-5**	**1**
20	-1	0	-1	0	0	0	0	**-5**	**1**

Figure 12: Pugh Chart of all twenty designs created by members of Team Foufou

Feasibility of each design was ranked on a 1 - 5 scale from not viable to viable, respectably. To determine the rankings we looked at the materials needed to produce the design, number of parts needed, ability to assemble with the equipment provided in the Mechanical Engineering Shop, and finally the cost of production and ability to keep it under the $400 constraint.

Each selection criteria and requirements were weighted depending on importance explained below (our weights are scaled from 1 to 3, from least to most important):

1. Assembly and Disassembly

Weighted: 3 - Assembly and disassembly is of very high importance because it affects various aspects of the operation and effectiveness of grinder. Being easy to assemble and disassemble means the parts can be taken apart easily, moved from the United States to Haiti, and moved around easily within Haiti. Easy disassembly allows it to be taken apart for cleaning or replacing individual parts or tuning them up. If it is too difficult to do this the grinder will not be able to be used for a long time. There are several big advantages for a product that easy to assemble and disassemble.

2. Durability

Weighted: 3 - Durability is also weighted very heavily because the machine needs to be made with material that will last for a long time. We are bringing this machine down to an area that is already low in resources and doesn't have the materials necessary to make repairs or replace many parts. If the grinder cannot last it will not be a useful and lasting tool in the Haitian community and will be scrapped after the grinder is broken.

3. Ease of Manufacturing

Weighted: 2 - Ease of manufacturing is slightly weighted less since all the parts will be bought and created here in the United States, the supplies we have much more expansive and accessible. It is still important because our project is under a time-constraint, we want parts that can be made more quickly and put together in a timely manner to meet our deadlines. This is more of an important aspect for our team and the success of our project.

4. Ease of Use

Weighted: 2 - Ease of use is important because when the final product is shipped down to Haiti, we want the grinder to be useable by anyone. We may have younger kids or older adults working to create the breadfruit flour, so the ability to use manual energy by varying strength is crucial. We also want the training time to be very minimal, the easier it is to use makes it more likely they will continue to use it.

5. Cost

Weighted: 1 - This requirement is set by the ME 450 class of under $400. Depending on material originally thought to be used when the concept designs were drawn, we estimated the price it would take to create. This is not as important because this does not affect our end users and in some cases a bit flexible for us to work around that proposed budget.

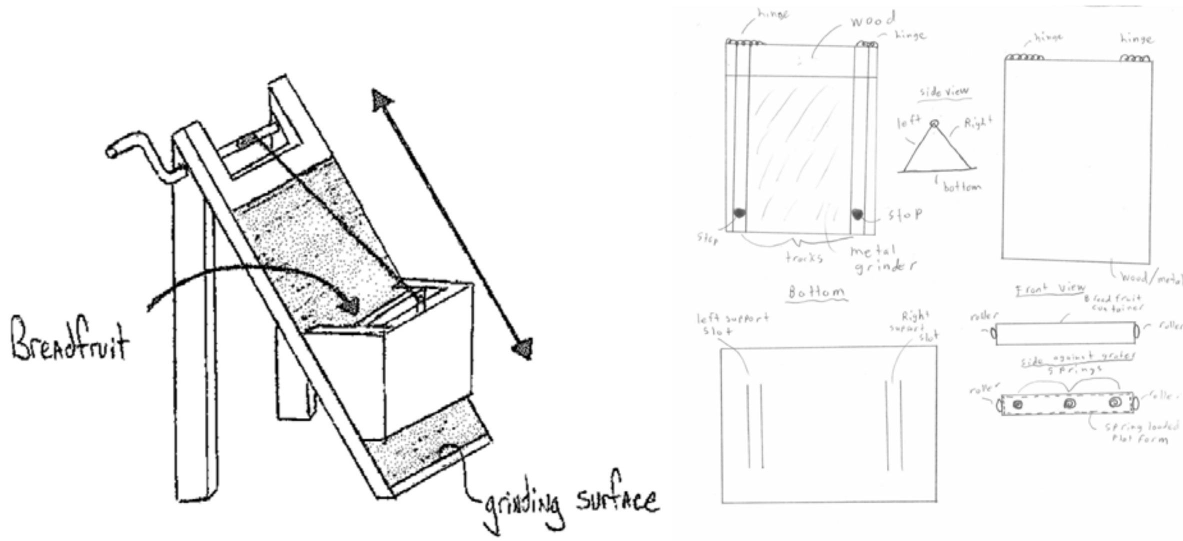
6. Size

Weighted: 1 - Size is also not as important because as long as the final product is able to create the breadfruit flour, that is the important key aspect. The importance of size is ability for transport and easier movement from point A to point B. And as well as easier storage and ability to use less space. This is not of primary importance because space is not in high demand, especially in areas we will be sending this to in Haiti.

7. Safety

Weighted: 1 - This is important because we don't want the user operating the grinder to injure or hurt themselves during operation, but since this is a manually-powered device, safety mainly depends on how carefully the user operates it. The open surface of the grater creates a hazard during operation as well as storage which will need to be improved upon during our design review process.

Using the Pugh Chart and setting the CTI Ewing IV as our baseline (see Figure 5), we ranked all twenty designs using the scale -1, 0, or 1 for each weighted requirement. From the numbers obtained, we were able to narrow down to two designs (Designs #3 and #9) we believe will be the most effective to achieve our final goal of creating breadfruit flour.



(a) (b)

Figure 13: Concept drawings of Designs #3 (a) and #9 (b).

Since Designs #3 and #9 were both in the grater category, we tested this basic form of grinding to ensure that the concepts will be successful. Breadfruit was not easily available to test, so dried potatoes were used instead. To get the size to be similar to the pieces of breadfruit that would result from the RIT shredder, we cut the potatoes into 3/8" cubes. Next, the shreds were dried out by placing them in a conventional oven for 2 hours at 120°F [24]. Rubbing the cubes along the finest face of the cheese grater produced a fine powder, thus supporting the basis for our chosen designs.

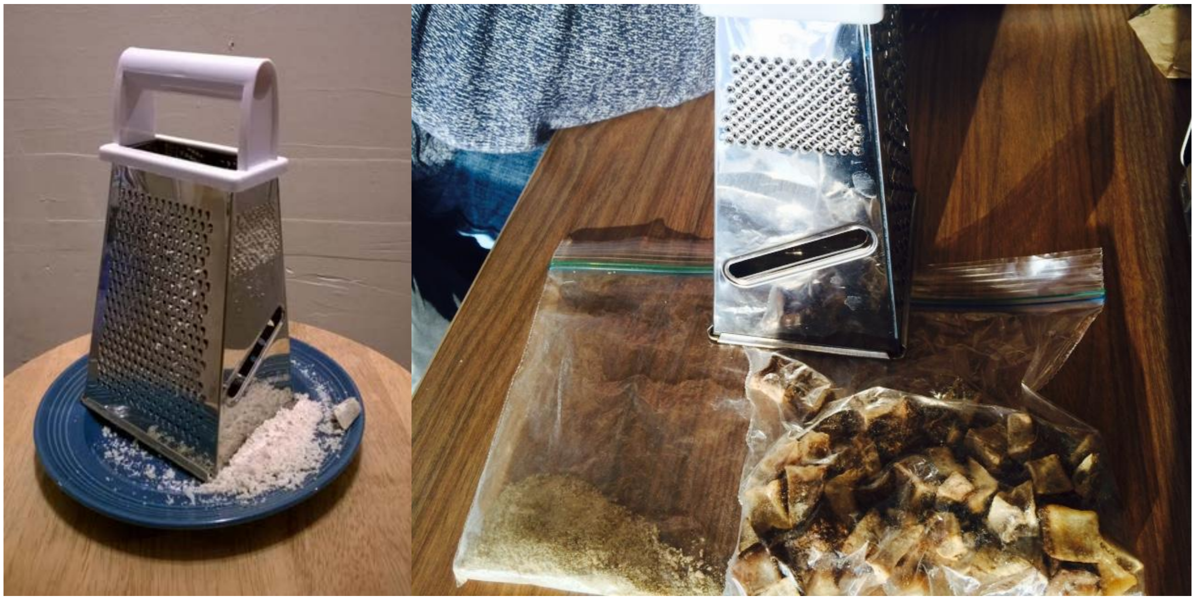


Figure 14: Dried potatoes grinded into potato flour using cheese grater.

The two concepts we combined seemed to be the best out of all the twenty different designs because after the testing of cheese grater we could ensure the idea was effective and had the results we wanted. The design also replicated the motion very closely for creating the potato flour, but just on a smaller scale. In terms of portability, the design could be folded down, stored, and transported easily which was one of our main requirements. The assembly of the design was also more straightforward than the other more complex designs. And the parts used are relatively simple and can be replicated if they breakdown. It gives the user the ability to make changes easy and make repairs which is of very high importance. Ease of use does not necessarily stand out among others but it offers a motion that is simple and a size that should allow for all ages to use. Cost, size, and safety are all aspects of this design that are met, they sit around the baseline we have set. Within this design a majority of its qualities exceed our expectations while others match our requirement and thus makes our chosen design concept an ideal one.

The two concepts we selected to combine had a couple advantages and disadvantages. The advantages were that it can be easily folded up and made into something very portable. The grater aspect is also quite intuitive and easy to use as well as easy cleaning. It can be folded down and brushed off easily to be used the next time. A disadvantage we encounter is the fact that there is an exposed side where the grater is present. This brings up safety concerns when using the device, but this will need to be solved by proper instructions of use and storage. The wearing of the grinder surface is also a disadvantage, but this comes with all designs. We will need to create a very tight tolerance with this design so the container will not be grinded and the breadfruit inside will not slip out when in use. Lastly, the grinder will not be able to continuously grind and must be perform its operation in batches.

Overall, the design we selected performs better than all other designs but also comes with its own set of advantages and disadvantages that we will need to overcome when we start creating the final design.

Key Design Drivers and Challenges

The engineering specifications that we have derived based on project requirements and the environmental factors unique to our task indicate that we have two major design drivers--factors that most heavily influence the design choices we make--and the challenges associated with them. We have acquired further information and understanding of the Haitian environment such as working condition and available resources since the first design review, and paid extra attention to ensure the compatibility of our design to the target environment of implementation.

The first design driver of our grinder is durability, since we deem the lack of resources and the low chance of adequate maintenance to be one of the most important challenges. Ms. Sarah Brownell has strongly emphasized that the resulting grinder should aim for semi-permanent implementation. According to Ms. Brownell, power grid is extremely limited in distribution, and only small numbers of generators and solar cells are present among the Haitian population especially those in rural areas. Also we were told to assume little to no access to scrap materials or any manufacturing tools to process them, which makes replacing or repairing parts very difficult. We have thus elected to minimize the number of moving parts in our grinder mechanism in order to reduce the chance of it failing during operation.

The second design driver of our grinder is the ease of use, as we have come to realize the importance of the grinder's ability to assimilate into the lives of Haitian farmers who grow breadfruit. It has been brought to our attention that despite the efforts of corporations and organizations such as Compatible Technology International and RIT, processing breadfruit crop into flour for storage and sale is not a widespread idea. In fact, RIT has initiated this project with the goal of developing a prototype that the local Haitians can try out to see the feasibility of turning breadfruit into flour. Therefore, we have agreed that building an easy-to-use grinder is critical, for it needs to have an advantage over what is already established among the Haitian farmers. To address this challenge, we implemented a very simple, intuitive grinding motion inspired by that of a conventional cheese grater, with which we have had some success already. The effectiveness of this grinding motion will be vigorously tested, benchmarked and verified.

Chosen Design Mockup

(a) (b) (c)

Figure 15: The three images shown above are pictures of the first mock up. Image (a) is a side view that emphasizes the ‘wet floor’ sign orientation when assembled for grinding, image (b) shows where the grinding surface would be, and how the breadfruit-loaded cartridge would be placed in relation to it, and image (c) shows the hatch-style door for easy breadfruit loading.

After the concepts were scored and the best concept was selected as discussed previously, we constructed a mock-up of our first prototype. It features a two-panel construction connected by hinges located at the top, so that, when erect, it resembles a conventional ‘wet floor’ sign used in buildings. The shaded surface shown in Figure 15(b) shows the grating surface comparable to that of the cheese grater (like shown in Figure 14). Given the slope of the grating surface during operation, the cartridge into which breadfruit pieces will be loaded is equipped with a hatch-style door as shown in Figure 15(c). The two white strips on the surface of the grating plate are rails onto which the cartridge will load, so that the grinding motion will be guided, and simplified as a result. Last but not least, the plate placed under the grater not only serves to hold the grater in place, but also acts as a reservoir where the ground breadfruit flour will be collected. Also, it should be noted that our mock up is built close to the actual size of the final machine we envision (i.e. scale of 1:1).

Through constructing the mock up we have gained some insights regarding the potential effectiveness of the prototype and its shortcomings. First of all, we have noticed that our prototype lacks the ability to adjust the angle of the grating surface, which as a result may cause ergonomic inconvenience. This has brought to our attention the need to consider ergonomics as a key element in improving our concept in the next iteration. Specifically, we will be focusing on determining effective heights, angles, and required force of grinding breadfruit.

Also, we noticed that our prototype’s open and simple construction may fail to prevent external contaminants from mixing with the resulting flour and breadfruit flour from escaping the reservoir. In addition, since the act of grinding requires the user to apply force not only in the direction along the rails but also toward the grating surface, the two panels need to be more robust than we had previously anticipated.

The key insights we have discussed above will be addressed thoroughly before the next design review, and the mock up will be revised accordingly.

DR3 Update

Although the preliminary testing with the cheese grater proved that the concept would effectively produce flour, we still had to test the design on a larger scale. No suppliers were found to produce large grating sheets with fine holes, so we explored the methods available for manufacturing one ourselves. Our first attempt at creating a grating sheet involved drilling several 1/16” holes into a 1/16” thick plate of aluminum. We then hammered a larger nail through each hole in order to extrude out the metal edge and create a sharp surface. This method proved ineffective as the nail did not cause the aluminum to deform.

A revision of this idea involved cutting small X’s in the material to press out instead of holes. Using the waterjet cutter, we cut a small square pattern of 1/16” X’s out of a 1/32” thick sheet of stainless steel. The X’s deformed outward much easier when hammered by a nail; however, the metal sheet deformed as each X was struck with the nail. Unfortunately, the grating surface we manufactured was severely inferior to the cheese grater we used for our initial testing. Creating a grating sheet to our desired size would require an unreasonable amount of time using the waterjet cutter and hammering out each individual X. Also, the pattern cut out of the steel would cause an excessive amount of stress on the waterjet machine. It was decided that a grater style breadfruit grinder is not feasible, and we had to consider other designs. Based on the resources available at the University of Michigan and suppliers, we chose to move forward with a roller design.

Concept Description

Based on the concept that breadfruit slices can be grinded into flour by crushing them with rollers, we chose a design with two abrasive cylinders, powered by a hand crank. Our grinder will consist of a hopper that feeds particles into the rollers, which mill the breadfruit into a flour that falls through into the bucket below. The assembly will mount to a base plate that prevents foreign objects from mixing with the flour. Figures 16, 17, and 18 illustrate our design in SolidWorks modeling software.

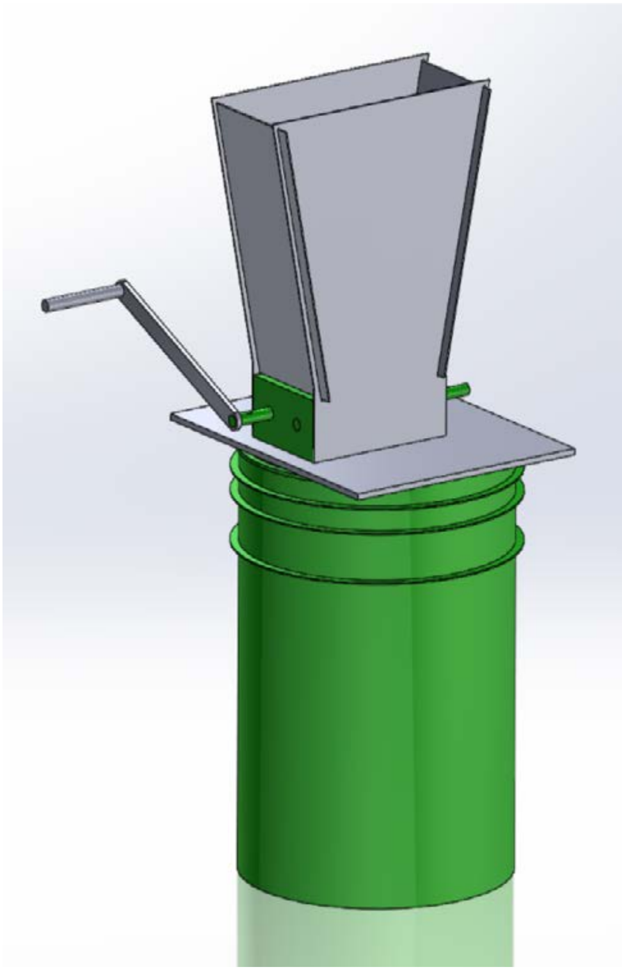


Figure 16: Complete assembly of grinder design.

The hand crank allows the user to continuously grind the breadfruit loaded in the hopper. One of the abrasive rollers can be adjusted to increase or decrease the gap size between the cylinders, accounting for the particles that need to be grinded. The two casings on either end of the rollers provide the structure of the device, attaching the grinding mechanism to the base plate and the hopper (refer to Figure 17).

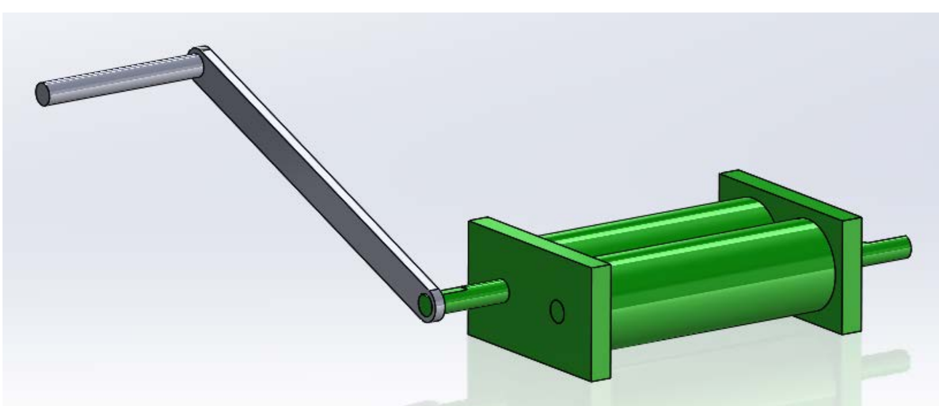


Figure 17: Roller and crank mechanism will grind the breadfruit into flour.

In order to ensure that the particles do not fall to the side of the rollers, or spin on top without being ground, the hopper sides (top and bottom in Figure 18) are angled inward and the hopper walls (left and right in Figure 18) contain angled lips to direct the breadfruit to the gap between the cylinders. The hopper can disassemble easily, as two of the sides slide and lock into the other two walls. Once disassembled, all of the components of the grinder, except the base plate, can fit into the bucket for easy storage and transportation; the base plate will provide the lid.

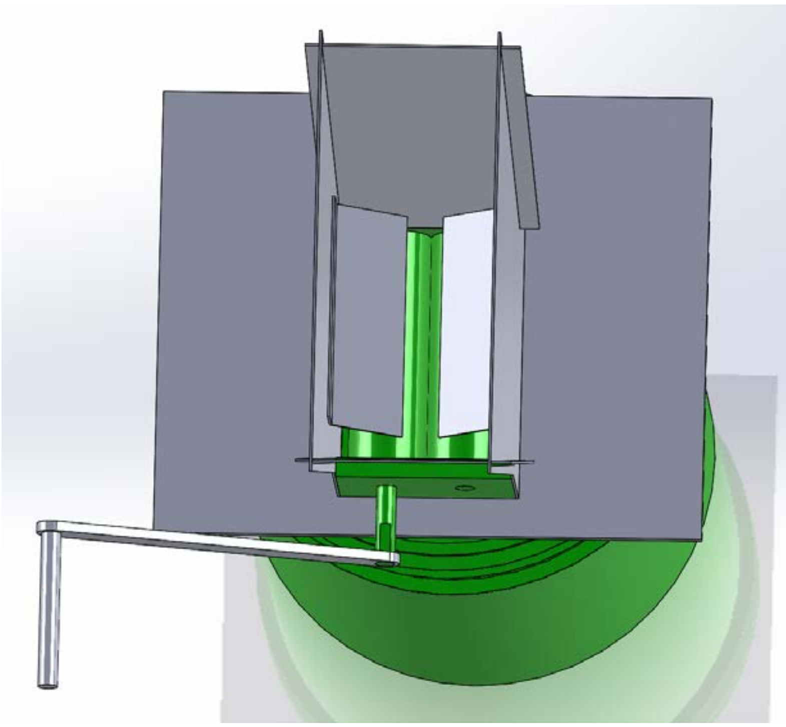


Figure 18: Top view of assembly shows the angled hopper components that funnel the particles into the center of the rollers.

Engineering Analysis

The key design drivers that we identified previously for our initial design are durability and the ease of use. The purpose of this section of the report is to further elaborate on these design drivers regarding the design from DR2. However, this is no longer applicable to the way our project is progressing, for we have since replaced the original design with another (grater concept to roller concept). Please refer to the DR2 deliverable for information pertinent to durability and ease of use of the grater concept.

The key design drivers for the no longer relevant grater design transfers over to our newly selected roller design, since the design drivers are derived from the most critical and significant design requirements we need to satisfy.

Durability remains to be our most important design driver for reasons very similar to our old concept. The grinder mills still need to crush and grind dried breadfruit shard without any metal shavings or contaminants mixed into the resulting flour. This will violate the food-grade related requirements of our project, which we have rated to be one of the most important that cannot be compromised. It is our goal to manufacture or purchase a pair of grinder mills that are not only capable of achieving the flour of right consistency, but also are durable for extended usage without wear.

Ease of use is also applicable for the newly selected design. The uniform motion of using the hand crank is arguably more straightforward and intuitive than that of our old design (cheese grater). However, now we need to confirm that from the ergonomics standpoint, the machine is easy and comfortable to operate. In order to address this issue, we will be conducting a thorough torque analysis—torque needed by the rollers to crush the breadfruit pieces, and the torque that the user needs to input to operate the grinder at an appropriate speed (measured in RPM). Our goal is to optimize the system to operate at 60 RPM without straining the user's arm, shoulder, or back. Means of benchmarking and setting ergonomic standards will be tested and solidified through trial and error, research in ergonomics, and consults with faculty members.

Solid mechanics and strength of materials will be the main means of analysis for our concept in order to determine the necessary force required to operate the machine and crush breadfruit. Dynamics may be utilized in analyzing the motion of the user when operating the hand crank.

To determine the validity of our design, several steps were taken to analyze our primary design driver of creating breadfruit flour using a specific grinder style. We were able to do theoretical modeling, empirical testing, and construct a mockup.

Empirical Testing

An empirical test was used to solve for the coefficient of friction of the dried potato. This value is necessary for our theoretical testing of the effectiveness of our rollers. Below is a force diagram used to find the coefficient of friction and a picture of the test we conducted.

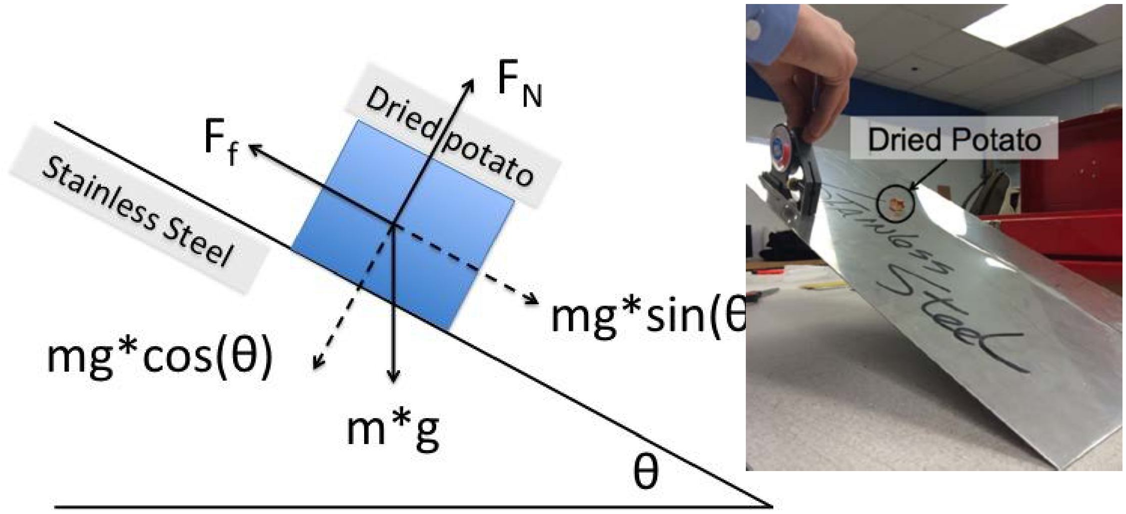


Figure 19: (Left) Free body diagram, (Right) Experimental testing of dried potato

These three equations were used in combination to solve for the coefficient of friction of a dried potato:

$$F_N = mg * \cos\theta \qquad \text{(Equation 1)}$$

where F_N = normal force, m = mass of dried potato, g = gravitational acceleration, and θ = tilt angle.

$$F_f = mg * \sin\theta \qquad \text{(Equation 2)}$$

where F_f = *friction force*, m = mass of dried potato, g = gravitational acceleration, and θ = tilt angle.

$$F_f = \mu_S * F_N \qquad \text{(Equation 3)}$$

where F_f = *friction force*, μ_s = coefficient of static friction, and F_N = normal force.

Test Procedure:

1) Cut potato into ⅜" cubes
2) Dry in oven for 10 hours at 120 degrees Fahrenheit
3) Place a cube of dried potato near the top of a stainless steel plate
4) Place an angle finder on plate and slowly lift end of plate until potato slides down
5) Record the angle
6) Repeat the test five times and find the average angle that the potato slides down

Results

After running our test a total of five times we found the angle of incline to be: ***θ* = 30 degrees**. This gave us the a **coefficient of static friction = 0.577**. We will use this information in the theoretical modeling for further analysis.

Theoretical Modeling

A feasibility analysis was conducted to determine what size rollers we will need for our design. Below is a diagram of the roller analysis we used:

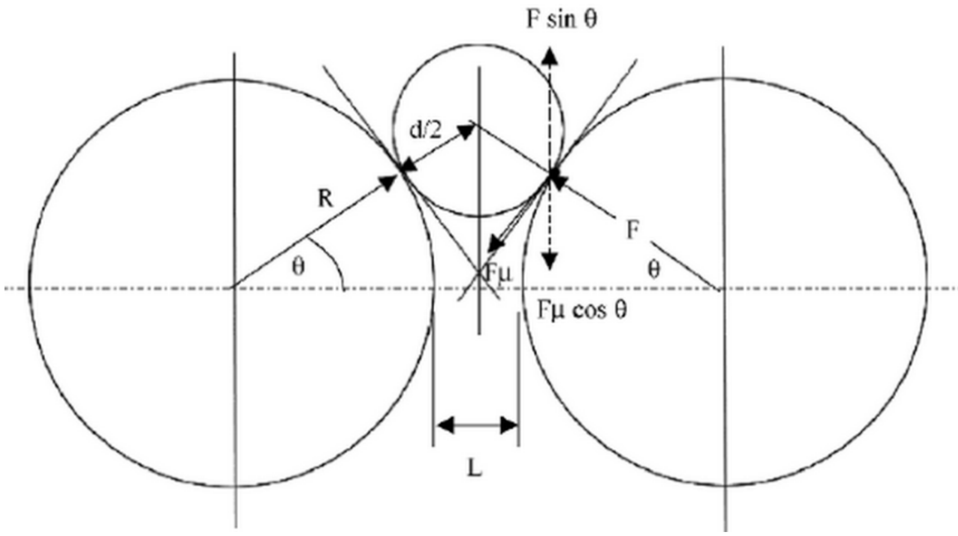


Figure 20: Roller diagram analysis

Using the textbook *"Mineral Processing Design and Operation: An Introduction"* by Gupta, A. and Yan, D.S., [25] we were able to make assumptions as well as obtain important roller crusher equations:

Assumptions:

- Small particle mass
- Spherical particles
- Smooth rollers
- Gap size directly related to final particle size
- Single point of contact with rollers

This equation determines the radius of the rollers necessary to crush the breadfruit with a set gap length, set diameter of the shredded and dried breadfruit, and angle of nip which constitutes the largest angle that will grip the shreds between the rollers. Below are the equations we used for our application:

$$R = \frac{[L - d * \cos(\theta)]}{[2 * \cos(\theta) - 2]} \qquad \text{(Equation 4)}$$

where R = radius of the rollers, L = length of gap between rollers, d = diameter of shredded and dried breadfruit, and θ = angle of nip.

$$\mu = \tan(\theta) \qquad \text{(Equation 5)}$$

where μ = coefficient of friction and θ = angle of nip.

$$\mu_{act} = \frac{[1 + 1.2\nu]}{[1 + 6\nu]} \mu_s \qquad \text{(Equation 6)}$$

where μ_{act} = coefficient of kinetic friction, v = angular velocity (RPM), and μ_s = coefficient of static friction.

Results
From the theoretical modeling based on the variables provided by the Monster MM2-Pro rollers.

- Assuming the constant roller gap of 0.16” manufactured by Monster: A calculated roller diameter of **1.23”** is required
- Assuming the constant roller diameter of 2” manufactured by Monster: A calculated gap length of **0.0568”** is required

This confirmed that the rollers by Monster MM2-Pro are feasible. Manufacturing of rollers in the machine shop is also an option.

Mockup Construction

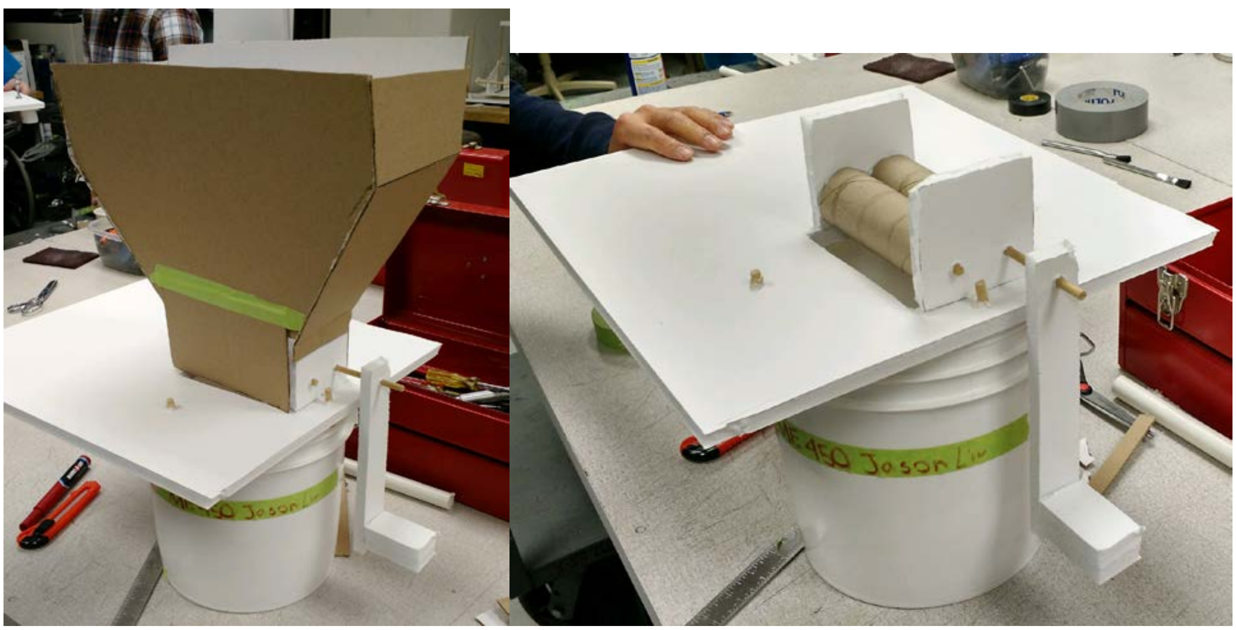


Figure 21: (Left) Entire mock-up with feeder on top, (Right) Clear view of roller design

Basic manufacturing process (refer to Manufacturing Plan for detailed plan):

- Feeder (aluminum) - metal press
- Rollers (stainless steel) - purchase/lathe
- Hand crank (aluminum) - purchase/mill
- Base plate (wood) - band saw and mill the base plate
- Bucket (plastic) - purchased

Basic assembly process:

- Basic nuts and bolts to hold feeder together and secure rollers
- Press bearings and insert axle for crank

Overall the material selection for our product is appropriate for our design. We were able to get a basic understanding of the difficulty involved with manufacturing the feeder. To create it in one piece we will have to measure angles very carefully and do analysis on the computer to ensure it fits properly together. The feeder height must be at a level that will not interfere with the user during operation. We validated that the design with the grinder over the bucket should provide the proper height to be used effectively. Constructing the mock-up allowed us to think about the problems that may arise and to visualize how it looks.

All three modes of analysis were able to be used for our design. We were able to find the coefficient of friction for dried potato, the appropriate size of the rollers and their gap length, and had some hands on for the mockup of the design. The level of detail was quite high utilizing ratios to determine part sizes. Our intent is to fit all parts into one 5-gallon bucket. The information for the nuts and bolts is not determined at this time as we are still unsure of where they should be located and what size they should be. We were able to determine a general guideline for part sizes and with some previous research and experience picked out materials best fit for this job. Since we are making food we will need to ensure that all materials used are food grade. The design seems functional and the concept has been used before so we have a baseline for success. A key feature that might need to be changed is the set-screw used to secure the clamp. We may need to change to a nut and bolt design to reduce maintenance issues that may arise. We have a 70% confidence that our roller design will work based on empirical and theoretical analysis, but since we haven't been able to do any empirical testing of grinding the dried potatoes ourselves, we cannot be certain it will work. Currently we don't see any technical issues present, but as we start finalizing the CAD model, some technical issues may occur. Further analysis of potential torque required to turn the crank may need to be done when our rollers are manufactured and testing of grain size created by the rollers will also need to accessed.

FMEA and Risk Analysis

Item / Function	Potential Failure mode	Potential Effect(s) of Failure	Sev	Class	Potential Cause(s)/Mechanism(s) of Failure	Occur	Current Design Controls	Detec	R.P.N.	Recommended Action(s)	Responsibility & Target Completion Date	Action Results: Actions Taken	Sev	Occ	Det	R.P.N.
MM2-Pro 2" Diameter Rollers																
Provides mechanism for grinding breadfruit	Obstruction of roller mechanism	Hand injury. Potential tissue damage and/or bone fracture	10		Accidental insertion of hand in between rollers	1		1	10	None	19-Mar-15	Include hopper lid to prevent hand insertion during roller operation	10	1	1	10
	Removal of roller surface in the form of metal shavings	Less effective grinding surface	7		Rolling contact fatigue failure	1	Heat treated stainless steel provided by supplier	2	14	None	19-Mar-15		7	1	2	14
		Potential ingestion of metal shavings during flour consumption	10		Roller material consists of metal of inadequate stiffness that lacks proper heat treating	1	Heat treated stainless steel provided by supplier	2	20	None	19-Mar-15		10	1	2	20
Hand Crank																
Rotates rollers	Dislocation of hand crank	Unable to operate grinding mechanism	8		Hand crank inadequately secured with set screw	3	None	3	72	None	19-Mar-15		8	3	3	72
Breadfruit hopper																
Collects and feeds breadfruit shreds into grinding mechanism	Obstruction of breadfruit feeding tube	Unable to feed breadfruit shreds into grinding mechanism	5		Breadfruit fed into hopper at too fast of a rate	2	Failure due to operator interaction rather than design	2	20	None	19-Mar-15		5	2	2	20
Collection container																
Collects ground breadfruit flour	Hole or crack compromising structural integrity of container	Loss of breadfruit flour	4		Improper storage of container resulting in over exposure to the elements	2	Failure due to operator interaction rather than design	1	8	None	19-Mar-15		4	2	1	8
		Exposure of flour to unhygienic conditions	4		Damage as a result of normal equipment operation	2	Failure due to operator interaction rather than design	1	8	None	19-Mar-15		4	2	1	8

Figure 22: FEMA Analysis

The aspect of our design with the highest risk is the hand crank. The hand crank is secured to the roller drive shaft using a standard set-screw. Based on previous experience it is known that set screws do not attach things as tightly as a bolt through a threaded hole would. A risk priority number of 72 indicates that this risk has a noticeably higher probability of occurring when compared to other risks. We believe that this negative side effect is overcome by the improvements in assembly and disassembly that this type of attachment provides. Failure of this attachment is highly unlikely to prevent personal injury, but would render the grinder unusable until the crank handle is re-attached. This can be easily accomplished with the accompanying Allen key in very little time. The success of this function is primarily focused on the user who will be required to tighten the set-screw on occasion. This risk priority number lies between the values of less than 30 which is considered reasonable and greater than 100 which indicates that failure is almost certain to occur. Had this number been associated with a mechanism that could result in personal injury or catastrophic equipment damage we would implement an appropriate design change, but given the current configuration we find an RPN value of 72 to be satisfactory and do not see the need for any design changes.

DR3 Current Challenges

The challenges we faced in the previous design review are no longer relevant. Between the DR2 and DR3 presentations however, we have experienced a significant challenge in realizing the ‘cheese-grater-like’ surface part of our original design. We have not been successful in finding a vendor or manufacturer from whom we can purchase said part of the design, and a downscale attempt at manually creating the surface turned out to be difficult and unrealistic. Consequently, we have addressed the issue by modifying our concept selection to one that is more similar to what the students at RIT originally selected, and drafted a new design that incorporates grinding rollers.

The first and most important challenge we face is obtaining a pair of grinding rollers that would satisfy our engineering requirements without going over our fixed budget of $400. The engineering analysis regarding the necessary roller radius and roller gap indicates that purchasing the MM2-Pro rollers from Monster Mill is a feasible option for our purposes, but configuring that roller to prevent issues such as metal shavings during operation—a critical issue that is yet to be solved for RIT’s initial prototype—could increase the price rapidly. In order to address this problem, we will conduct budget analyses on the parts and materials prior to making the decision on whether the rollers are going to be manufactured or purchased. Also, we have confirmed that a local homebrew store has the MM2-Pro grinder in stock and on display for demonstration. Should we decide on purchasing the rollers to be more feasible, we can visit the store to test the grinders before making the big purchase.

If we choose to manufacture the grinder rollers, then we run into the challenge of ensuring that the rollers satisfy all our engineering requirements—most importantly the requirement regarding durability. RIT’s prototype’s biggest problem was the metal shavings that started accumulating from the rollers’ wear. Communication with the RIT student team has revealed that the problem was due to their prototype being made of untreated (heat-treatment) aluminum—RIT’s benchmarks confirm that aluminum, therefore, is not hard enough to grind dried potatoes, let alone breadfruit, for consumption purposes. We plan on addressing this issue by first manufacturing the rollers with stainless steel (which is possible as confirmed by the machine shop crew) and then conducting the same benchmarks that the RIT team did. If said benchmark indicates that untreated stainless steel has the same problem, then we would need to consult professor Kannatey-Asibu to find out if resources are available to somehow treat the stainless steel roller. This consultation will be conducted prior to deciding whether or not the rollers are to be manufactured, for the availability of metal-treatment resources may impact the decision.

The final challenge that we foresee in the coming design period is the ergonomic testing needed to ensure the design's usability. In order to ensure that our machine is easy to use, we need to optimize the gap length between the grinder rollers, and identify the torque required to operate the machine at the optimized configuration. If the torque analysis and empirical torque testing proves that our machine is difficult to operate, then design changes must be made to address that. In order to address this issue, we are prioritizing the building of a prototype grinder module with the hand crank to start benchmarking as soon as possible. A spring-loaded force gauge is most likely going to be used to measure the input force required by the user.

Initial Manufacturing Plan

Since our analysis suggests that the Monster Mill MM2-Pro grain mill will successfully grind breadfruit, we based our design around using this product as the basis for our grinder. In Figures 16-18, we colored all of the parts we plan on purchasing in green. We plan on manufacturing the hopper, crank, and base plate using stock metal and wood. The hopper will consist of four sides and two angle brackets that will funnel the breadfruit into the rollers. Two hopper walls will be bolted to the casing of the MM2-Pro, and two removable hopper sides will be locked into slots in the hopper walls. Two funnel lips will be riveted to the hopper walls, ensuring that the breadfruit will fall into the gap between the rollers so that it can be crushed. The handle will consist of a handle pressed into an arm that bolts to the shaft of the rollers, delivering the necessary torque. This whole assembly will bolt to a base plate that allows grinded particles to fall into the purchased 5 gallon bucket, while preventing foreign objects from falling in with the powder. The bill of materials for these parts can be found in Appendix B.

Most of the manufacturing will be done using the waterjet cutter, as the majority of the parts will be made from flat stock. The hopper components and the crank arm will be cut on the waterjet machine followed by further machining. This method is advantageous because the machine provides precise geometrical cuts and saves a great deal of time; however, the downside is that the part dimensions will have to be finalized when using the waterjet cutter. Adjustments to the parts will not be possible once they are cut from the sheet metal. The individual manufacturing plans can be found in Appendix B.

Updated Documentation

Refer to Appendix B for bill of materials, manufacturing plans, and drawings.

Changes in Design since Design Review #4

The changes done to our design after DR#4 was minimal since our initial design was already quite established. Since our manufacturing went smoothly and the assembly process was successful we did not see any changes needed to be implemented. Listed below are the Engineering Change Notices (ECN):

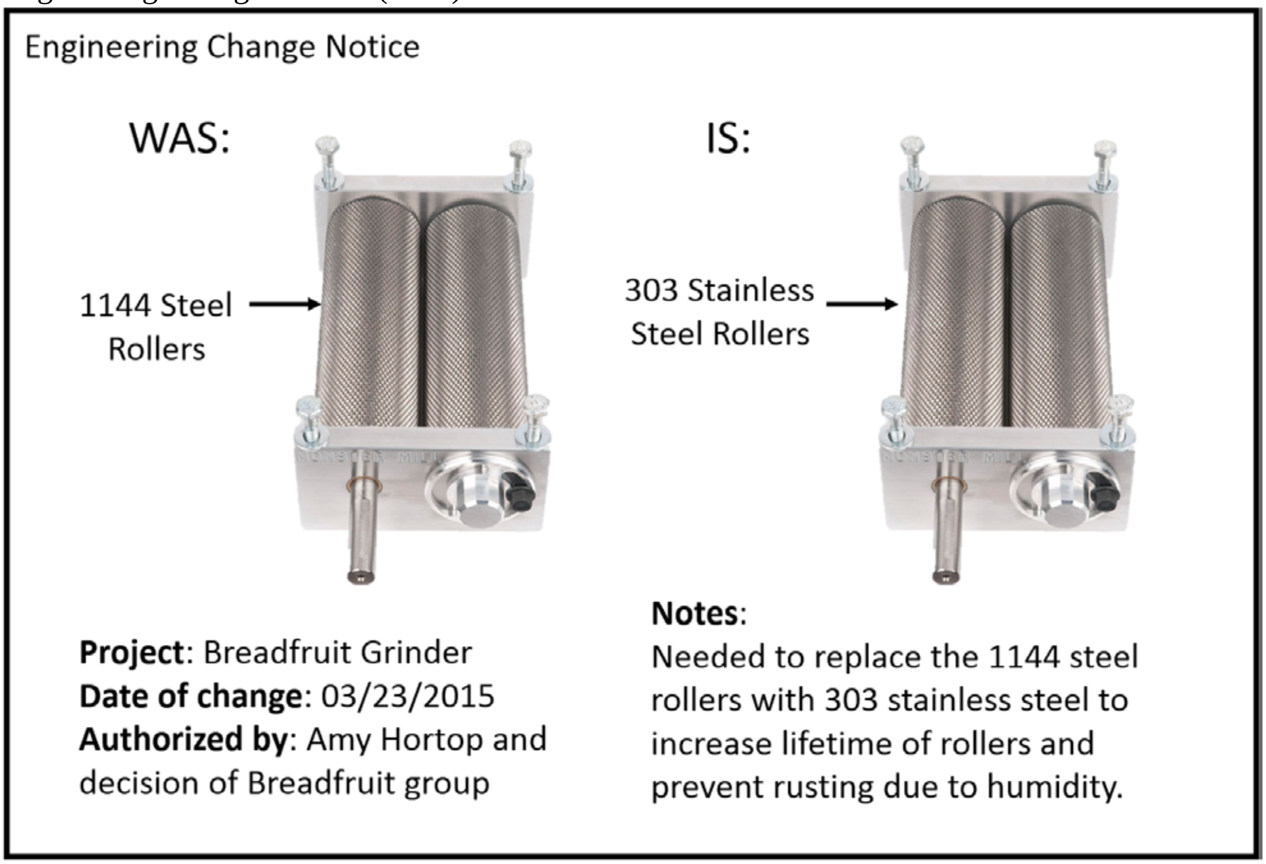


Figure 23: Engineering Change Notice of rollers from 1144 steel rollers to 303 stainless steel rollers

Validation Protocol Expectations

Refer to Appendix C for validated results of breadfruit grinder.

1. What will you need to measure?
2. What equipment will you use?
3. What are the basic steps you will follow in order to acquire your data?
4. How will you process your data in order to find a useful and significant result? i.e. Will you be filtering data from one or more sensors? What statistical analysis will you be performing?

Producing breadfruit flour (Grain size, Gap size, Number of passes)

1. Particle size of the flour we created will need to be measured.
2. Mesh strainer to shake out the particles that will pass.
3. 70% pass volume through the mesh strainer.
4. Run the breadfruit through the grinder and determine how many passes it takes for 70% of the volume grinded goes through the mesh.

Edible and safe breadfruit flour

1. Do tests of grinder and make sure no metal shavings fall into flour
2. Our prototype and our naked eye will be used to determine the safety of flour
3. Run the grinder and test with the dried potatoes.
4. Run the grinder

Overall safety for user

1. Gap sizes to insert fingers
2. Calipers and our own finger sizes
3. Look at the openings in our prototype that may cause fingers to get stuck or come in contact with moving parts.
4. Determine where dangers may occur and try and determine how we design safety precautions that can prevent it from happening

Manual energy: required torque

1. The amount of force required to initiate the grinding operation and the force required to continually operate the machine at ~60RPM
2. Spring-loaded force meter
3. With a standardize amount of dried potato placed between the grinding rollers, the force meter will be attached to the handle and pulled for the aforementioned cases of operation
4. Multiple sets of experiments will be conducted to take error into account and compare the result to tabulated values of required force for generic actions. Then draw conclusion/comment on the ease of operation

Ease of use and assembly

1. Measure the number of steps required for user to fully assemble the grinder and the time it takes for a full assembly
2. Completed assembly manual for counting required steps, and a stopwatch to measure the average time required for full assembly
3. Devise the most effective way to assemble the machine and make a manual clearly labeled with step-by-step instruction. Then using that manual, each member of the team will assemble the machine with a stopwatch to determine the average time of assembly
4. The result will be compared with our initial engineering requirement of (under X minutes) to produce statement regarding the ease of assembly and disassembly

Easy to clean

1. The efficacy of fruit/vegetable residue removal
2. Toothbrush and water
3. Run the grinder using dried potato cubes (~10 runs), disassemble the grinder, and use water and toothbrush to manually clean the rollers of any residue

4. The qualitative result (i.e. visible residue, smell, color etc.) will be observed and recorded. The goal is near-total removal of any and all fruit/vegetable residue

Weight
1. The total weight of all the components of the grinder
2. Large scale
3. Fully assemble the grinder and place it on the scale to measure the exact weight h
4. Considering the precision and resolution errors in mind, we will determine the exact weight of our machine and see if it fits our initial engineering specification of 50lbs<

Size
1. We will need to:
   i. Measure the height, width, and length of the grinder when fully assembled
   ii. Confirm how many of the components can fit inside the bucket as initially envisioned
2. Scale (ruler, tape measure, calipers) and the bucket used for grinder design
3. Measure the dimensions taking into account precision and resolution errors
4. We will statistically confirm at what height the end user will be operating the machine and also solidify the optimum way to arrange the components to best fit them inside the bucket

Individual Assignments

Refer to Appendix D for the individual statements below:
- Ethical design statement
- Environmental Impact Statement

Discussion

Having spent many hours designing, building, and using our breadfruit grinder prototype, we as a team could thoroughly analyze its strength and weaknesses, along with what could have been done differently to improve its performance had we been given more time and resources.
The two true strengths of our prototype are the following:
1. <u>Portability</u>
   One of the key features that sets our design apart from other fruit and vegetable grinders that are on the market right now is the fact that all of its components, when disassembled, along with tools necessary to assemble and maintain the grinder fit into a 5-gallon bucket. It should also be noted that everything inside the bucket weighs approximately 22 lbs. We were given the task to design a grinder that is to be used and maintained in Haiti. While the sponsor did not require that the machine be designed for manufacturing in Haiti using its local resources, we still wanted to account for the future user experience. Having the multi-purpose bucket serve as the base and the flour collecting compartment of the grinder grants the users to replace the bucket with whatever they want and ultimately gives the design more flexibility. Also, keeping the design compact and under 50 lbs. not only makes transporting the prototype over to Haiti easy (through commercial

airlines), but also makes transporting it within Haiti depending on the needs of the end-user simple too.

2. Approachability
   As a part of the design, we prioritized simplifying the assembly process through means such as reducing the number of bolts needed to hold together the grinder and minimizing the use of tools. Also, we have carefully designed and included an intuitive, simple to follow assembly manual that also includes how the user should arrange the components inside the bucket to ensure a safe and snug fit. Lastly, the manual addresses some of the safety hazards that could arise from certain user behavior.

The two weaknesses of our prototype are the following:

1. The multi-pass method of grinding breadfruit
   Our grinder requires the users to adjust the gap sizes of the knurled rollers according to the particle size of the dried breadfruit. This means that in order to achieve the flour-like consistency, the user needs to pass the shredded breadfruit multiple times, while adjusting the roller gap size in between those passes. As demonstrated during our expo, the process is not very smooth. Peers have suggested that we implement a multi-roller system in which multiple pairs of rollers with different gap lengths would simplify the process. However, that solution is not feasible given our budget, size, and weight requirement of the design.
2. Consistency of the resulting flour
   Some members of the audience have pointed out that our end product is not as fine-grained as the commercial wheat flour used for baking. While we agree to that statement, we have confirmed through testing and validation that such is the limitation of the hand-powered knurled rollers. This weakness in design however, is a compromise between the engineering requirements and the specifications given by the sponsor and potential users.

   The two main weaknesses of our prototype mentioned above can be improved with an increase in project budget or access to certain resources that had not been available to us. Increasing the budget would allow us to purchase more necessary components such as extra grinder rollers or gears. What we would have preferred however, is access to additional resources. We have encountered some skepticism regarding purchased rollers, but that was a decision we reached after multiple failures of manufacturing the knurled rollers. If we had access to more accurate lathes for knurling or heat-treating equipment, not only would we have had the option of acquiring the rollers for cheaper, but also considered manufacturing other grinding mechanisms such as burr-disks which, during our concept selection process, exhibited higher potential for finer flour.

Recommendations:

1. If our prototype was to be improved upon, we recommend that the sponsor or the end-user focus on improving the transitioning process between the multiple passes required for reducing particle sizes. This could be achieved by improved roller gap managing mechanism (e.g. spring-loaded side bolts).
2. One way to significantly increase the performance of our grinder prototype is shredding the breadfruit to a smaller size than what we were given. If the shredder-building team at

RIT can devise a device that can produce smaller breadfruit particles, the product of the three-step process will be of much higher quality.

3. Studying the exact environment and resource availability of the community in which the grinder will be implemented would change the design process in a positive manner. Our force analysis and its validation have proved that while the force (and torque) required to operate our prototype is appropriate for hand-operation, it is certainly not ergonomically optimal. The team agrees that implementing a foot-powered grinder will yield better results in producing flour and making the operation less harsh for the user.
4. If this project is going to be continued, we recommend that the sponsor restructure the project that requires both teams at Michigan and RIT to collaborate more closely. The involvement of the RIT teams (shredder and dryer teams) were close to none after the initial encounter facilitated by Professor DeBartolo and Amy, and both teams fell completely out of contact when we needed some questions answered. This has, at few instances, slowed down our design process and had even led to problems that we needed to remedy along the way. The inconvenience from the lack of communications occurred far more and thus outweighed any benefits from the collaborative efforts that could have resulted from the project.

Final Prototype and Results

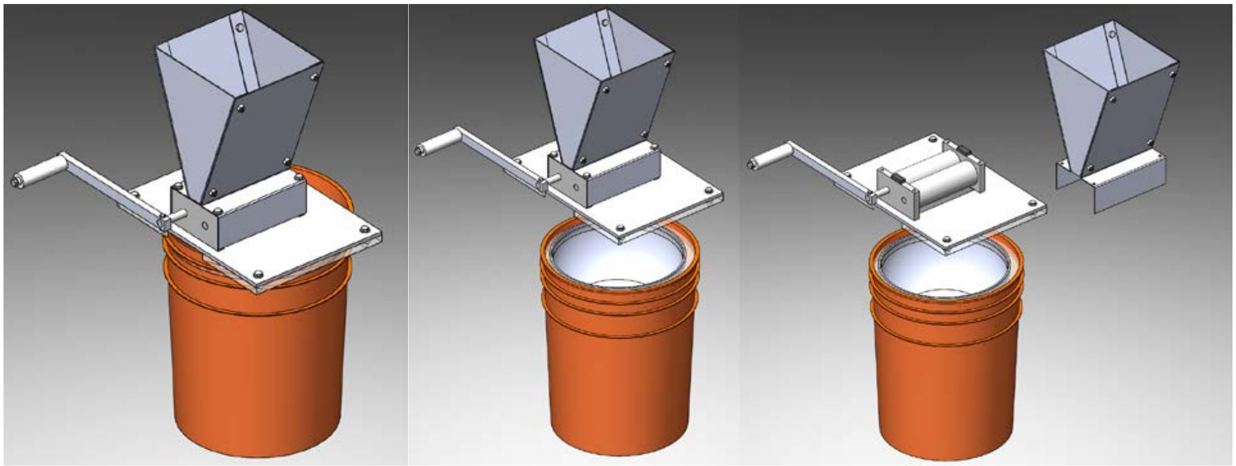


Figure 24: CAD View of Final Breadfruit grinder Prototype

Figure 25: Final Breadfruit Grinder prototype


Figure 26: Final result of grinded dried potato through our grinder

Appendix A

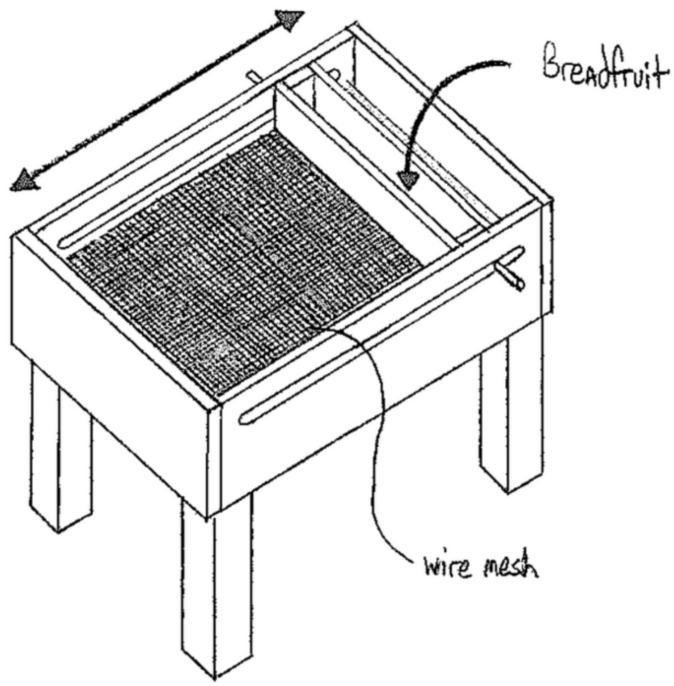


Figure A.1: Design #1

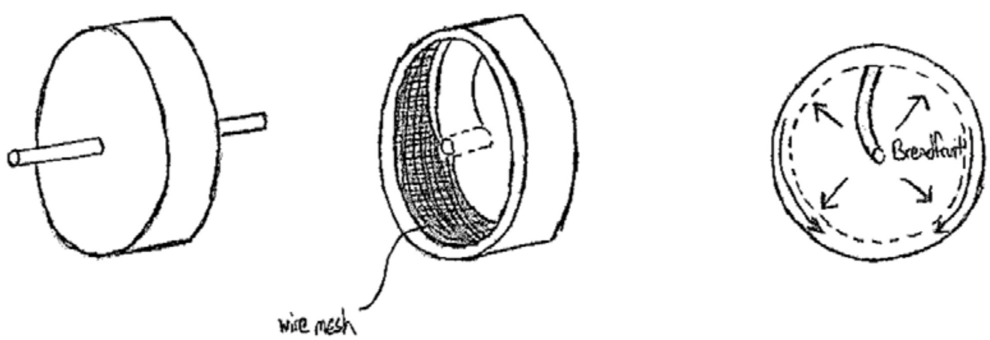


Figure A.2: Design #2

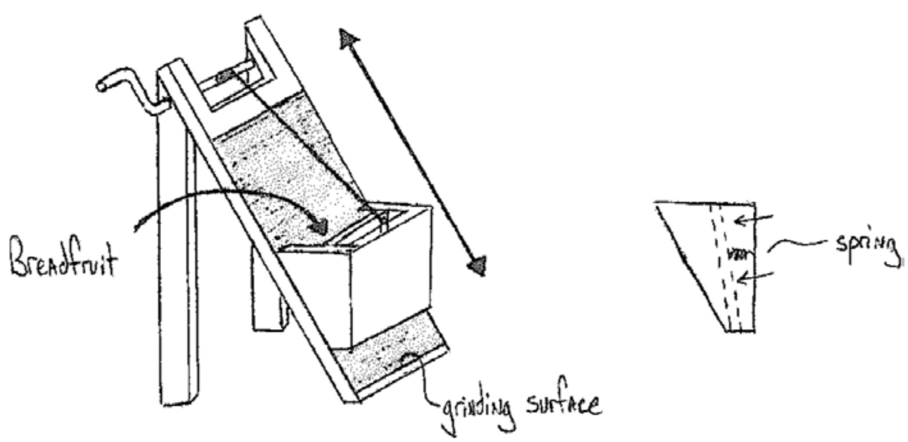


Figure A.3: Design #3

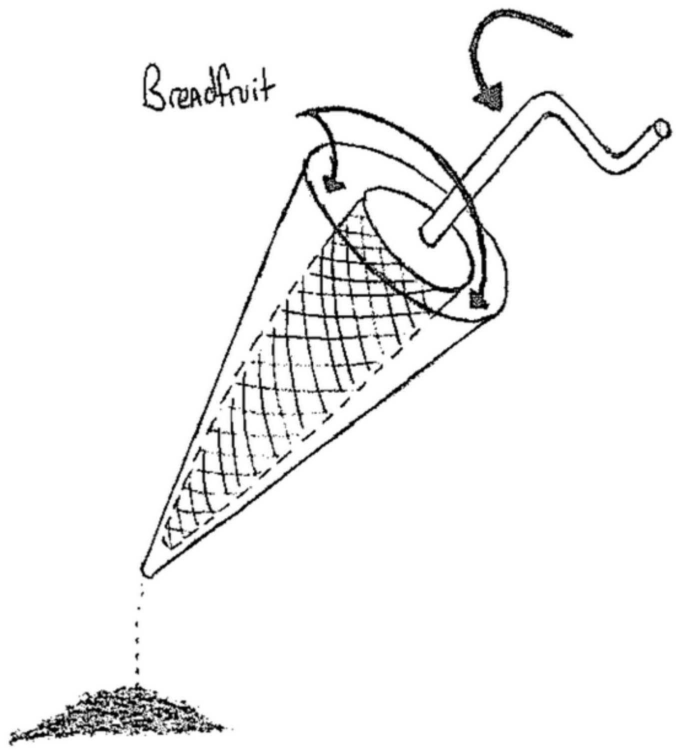


Figure A.4: Design #4

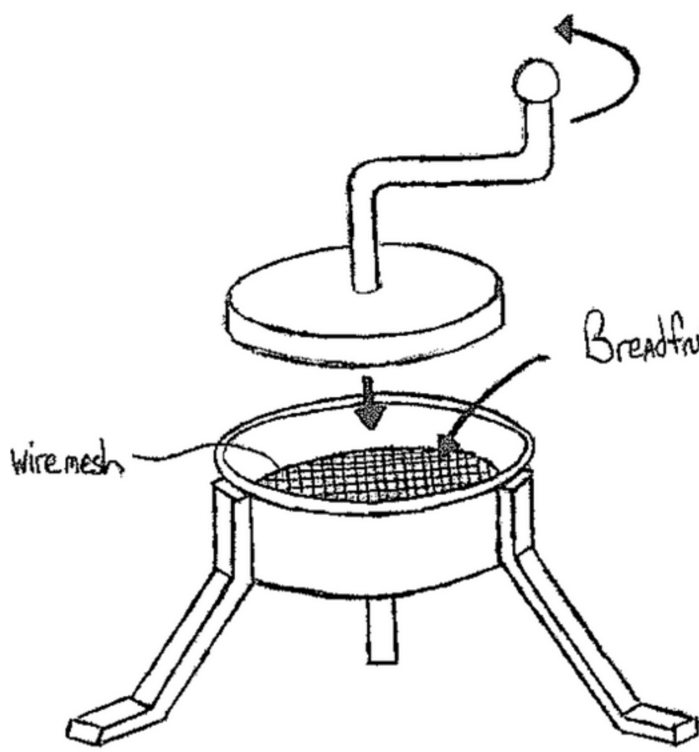
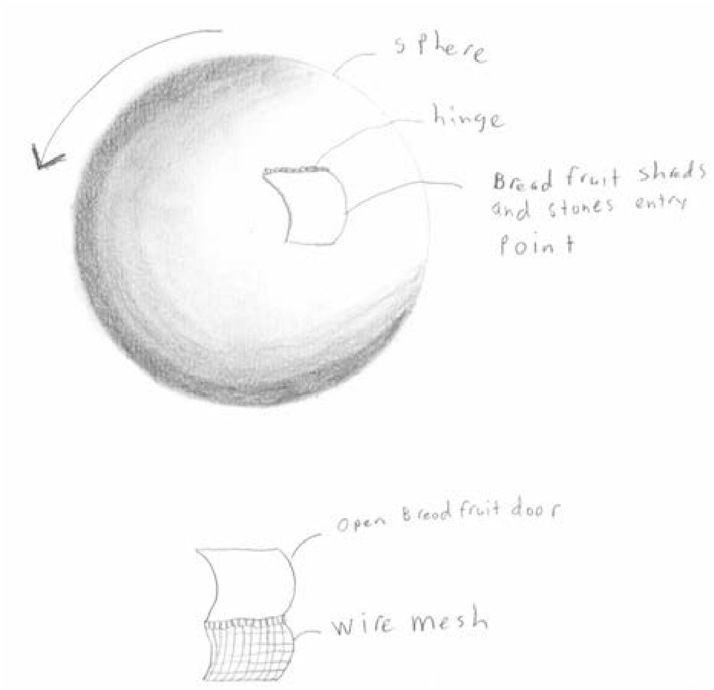


Figure A.5: Design #5



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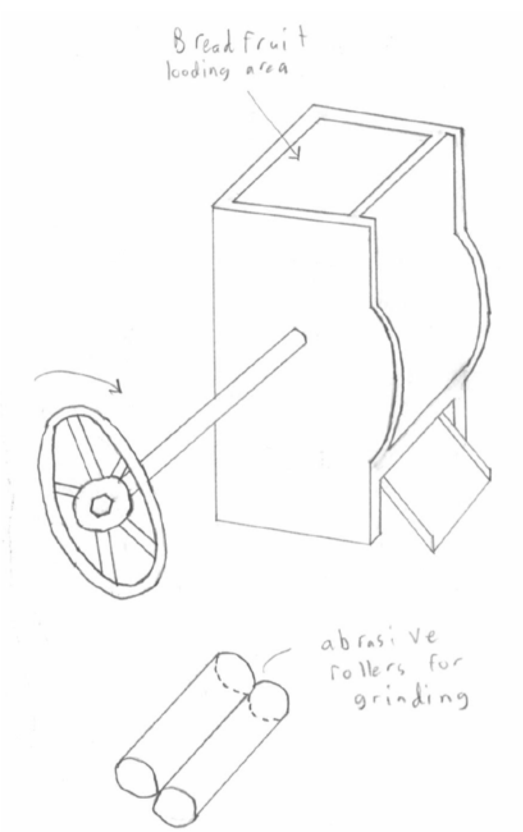


Figure A.7: Design #7

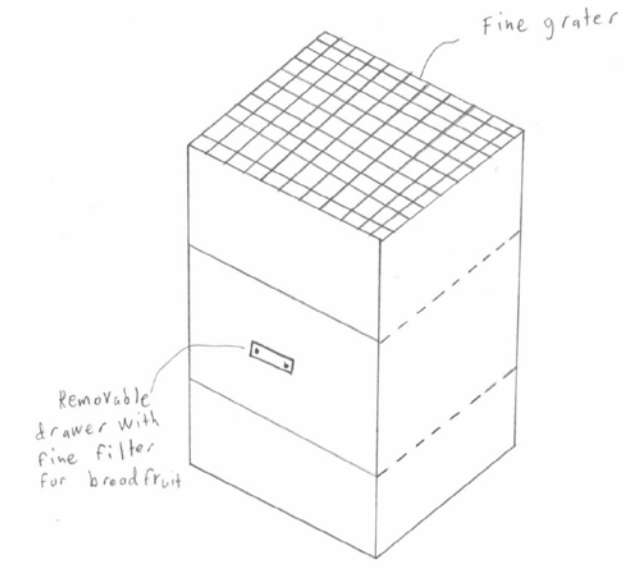


Figure A.8: Design #8

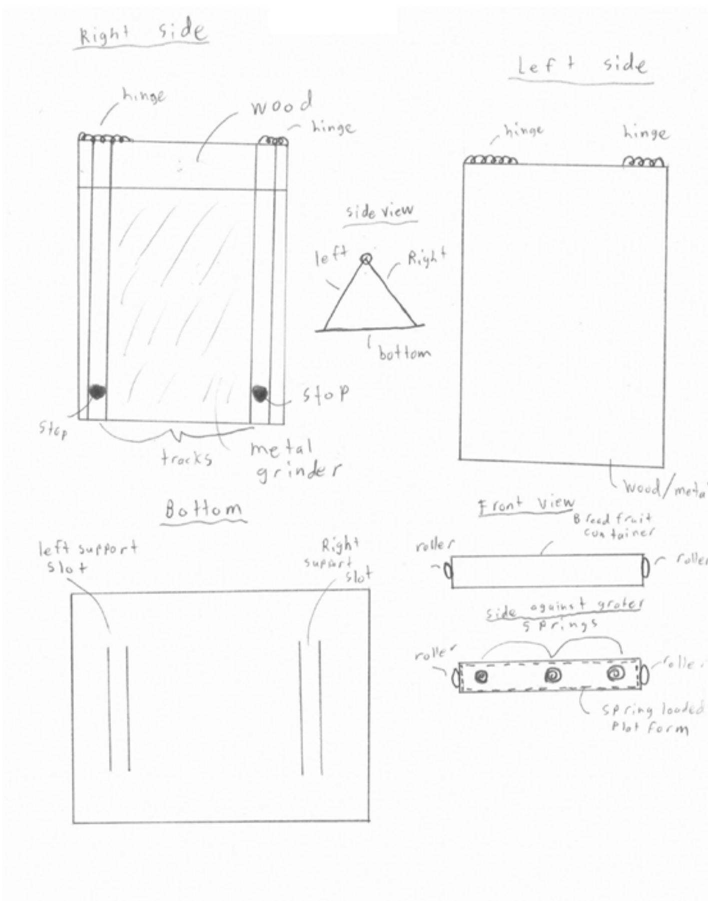


Figure A.9: Design #9

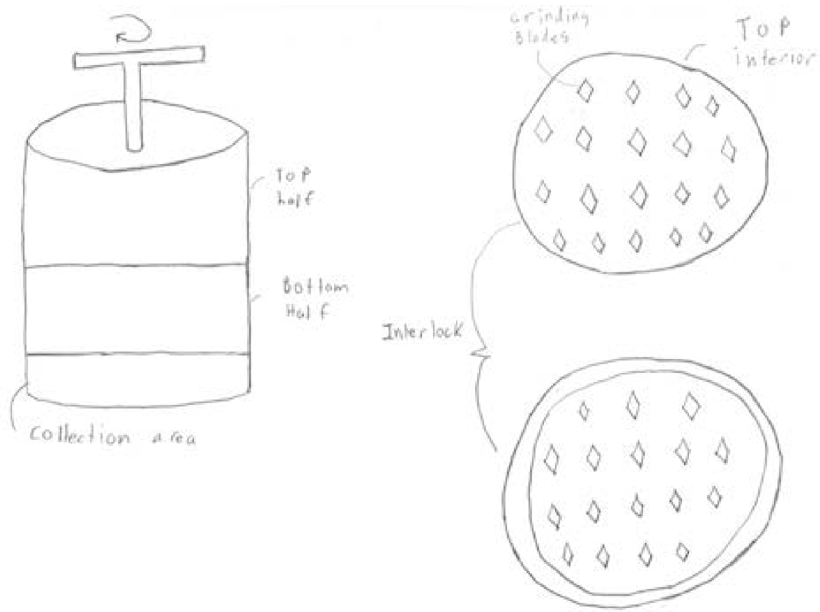


Figure A.10: Design #10

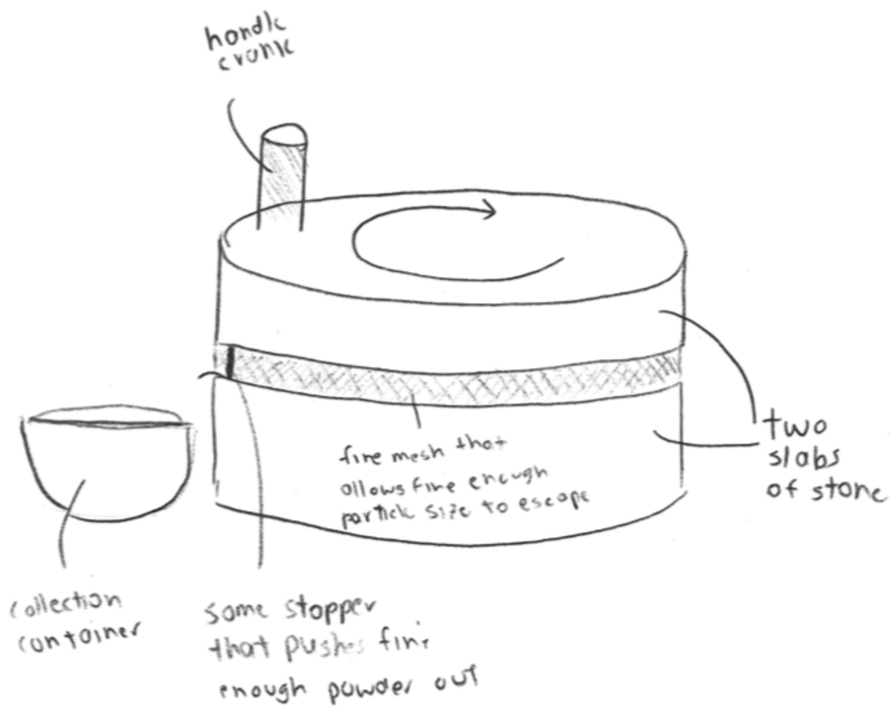


Figure A.11: Design #11

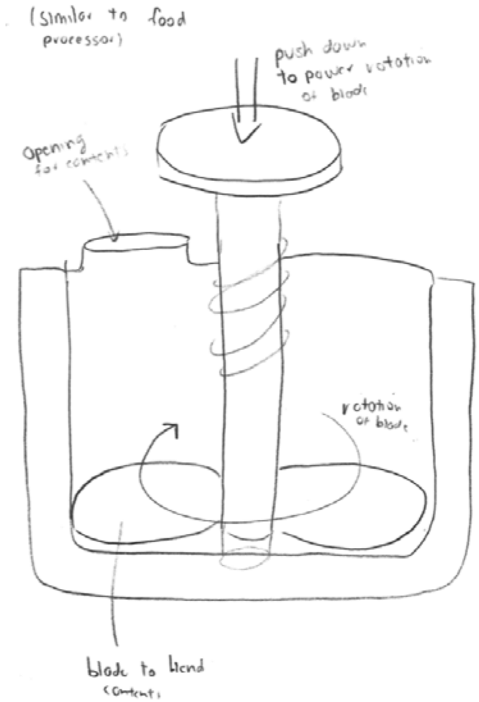


Figure A.12: Design #12

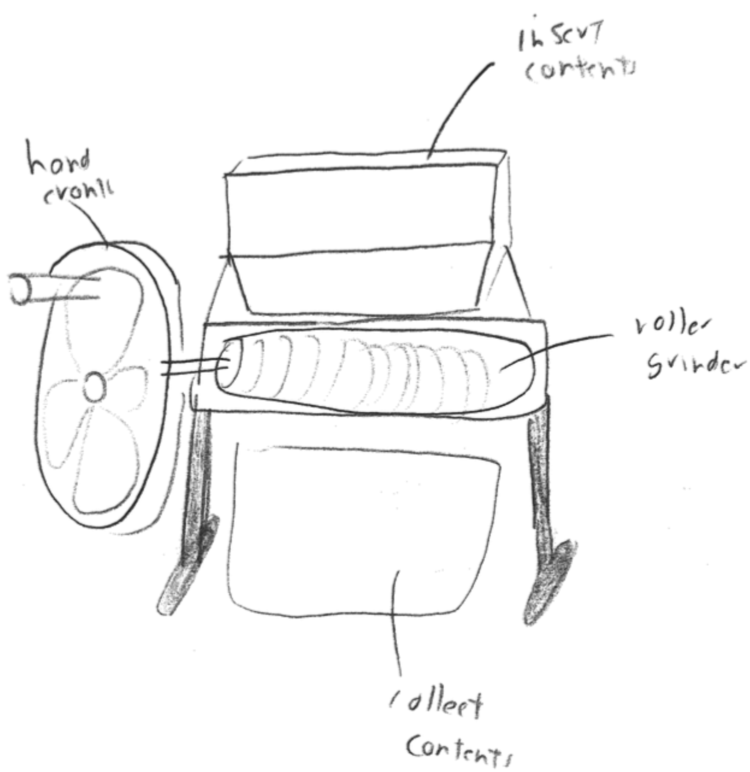


Figure A.13: Design #13

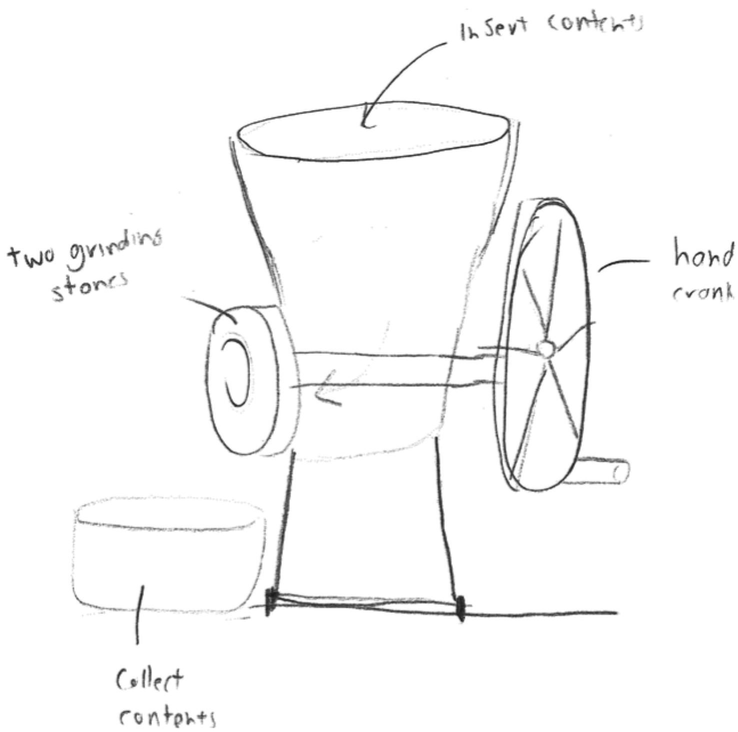


Figure A.14: Design #14

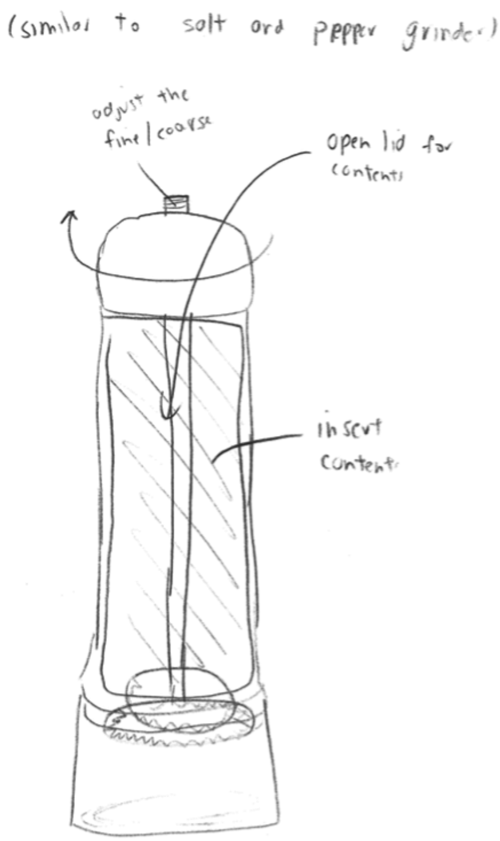
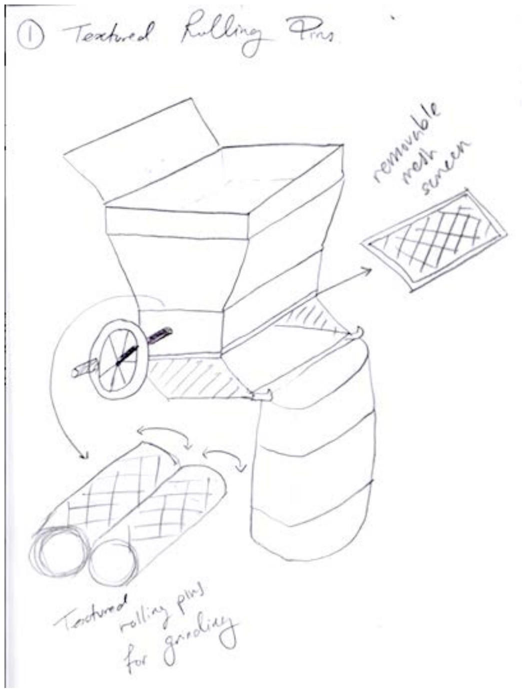


Figure A.15: Design #15



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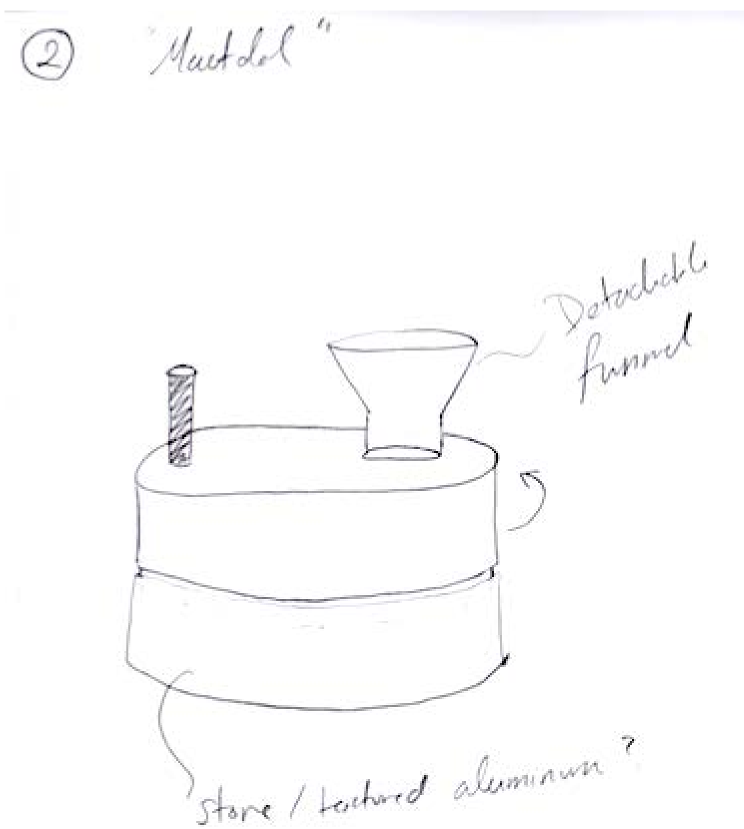

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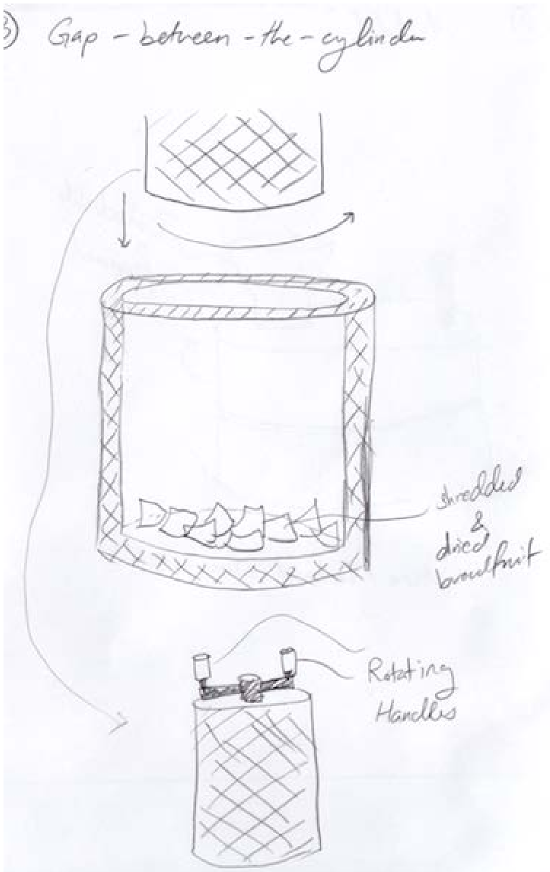

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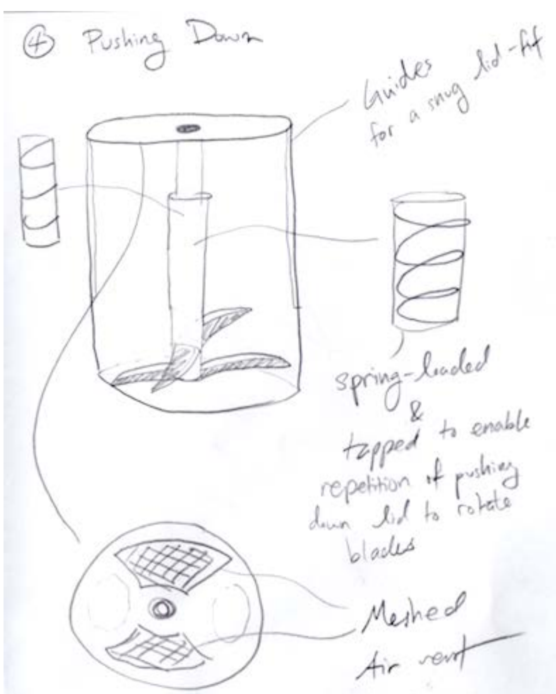


Figure A.19: Design #19

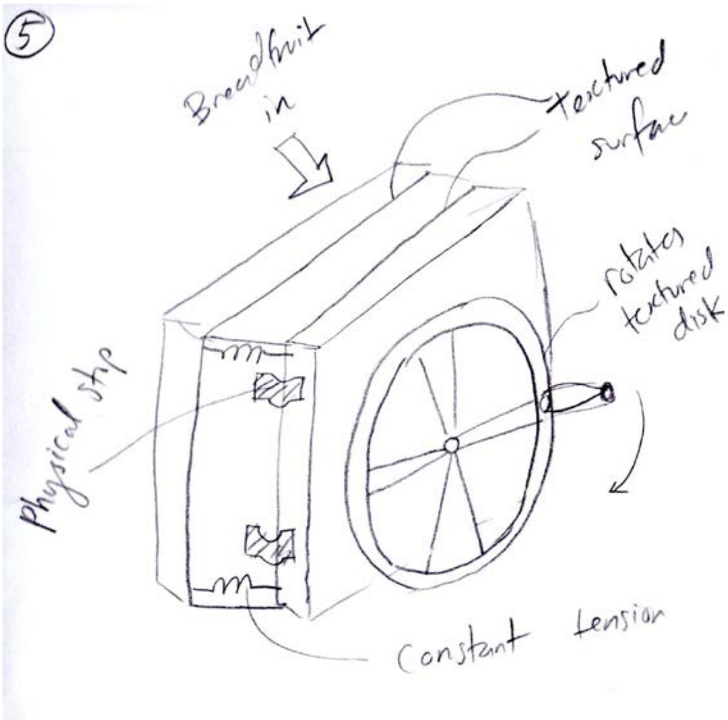


Figure A.20: Design #20

Appendix B

Figure B.1: Bill of Materials

Bill of Materials							
#	Description	Part	Dimensions	Supplier	Part Number	Quantity	Individual Price
1	Grain Mill Assembly	Grinder (w/ 303 SS Roller upgrade)	N/A	Monster Mill	MM2-Pro	1	$299.00
2	1/16" Aluminum Flat Stock	Hopper Side A	7.25" x 14"	McMaster Carr	5865T13	2	$4.21
3	1/16" Aluminum Flat Stock	Hopper Side B	10" x 10"	McMaster Carr	5865T13	2	$4.14
4	1/2" Aluminum Flat Stock	Crank Arm	9" x 3/4"	McMaster Carr	5865T771	1	$5.31
5	1/4" Aluminum Round Stock	Crank Handle	5" length	McMaster Carr	7237K18	1	$0.48
6	1" Delrin Round Stock	Crank Handle Sleeve	4" length	McMaster Carr	8572K61	1	$1.84
7	Plastic Bucket	Bucket	5 Gallon	Home Depot	05GLHD2	1	$2.97
8	Plastic Bucket Lid	Bucket	5 Gallon	Home Depot	209317	1	$1.38
9	1/2" Thick PE Cutting Board	Base Plate	10" x 14"	Update International	CB-1824	1	$4.57
10	Kitchen Strainer	Sifter	N/A	Grand Gourmet	Set of 3 Strainers	1	$3.53
11	Toothbrush	Cleaning Brush	N/A	WalMart	226958	1	$1.98
12	1/4" Acrylic Flat Stock	Strainer Rim	12" x 12"	McMaster Carr	8560K354	1	$16.36
13	1/2" Acrylic Flat Stock	Baseplate Extension	5" x 10"	McMaster Carr	8560K266	2	$9.13
14	1/8" Nylon Cord	Strainer Handle	2' length	Home Depot	14068	1	$1.96
15	1/4" Delrin Flat Stock	Gap Blocker	1.5" x 0.5"	McMaster Carr	8739K19	2	$0.22
16	1/4-20 Spade Head Thumb Screw	Thumb Screw	3/4" length	Jack's Hardware	N/A	2	$1.21
17	1/4-20 Bolt	Fastener	1.25" length	McMaster Carr	91236A544	4	$0.06
18	1/4-20 Bolt	Fastener	1" length	McMaster Carr	91309A542	13	$0.06
19	1/4-20 Bolt	Fastener	1/2" length	McMaster Carr	91309A537	8	$0.03
20	1/4-20 Nut	Fastener	N/A	McMaster Carr	93827A211	12	$0.07
21	High-Strength 10-24 Bolt	Fastener	1" length	McMaster Carr	92620A414	1	$0.49
22	10-24 Nut	Fastener	N/A	McMaster Carr	90480A011	3	$0.02
23	1/4" Flat Washer	Fastener	N/A	McMaster Carr	90107A029	19	$0.08
24	10-20 Eyebolt	Strainer Rim	1" length	McMaster Carr	9489T47	1	$0.23
25	Adjustable Wrench	Tool	4" Size	Meijer	2020923001	2	$5.99
	Revision Date:	4/20/2015				Total Price	$393.51

Figure B.2: Manufacturing plan for Crank Handle

Team Number:	ME450-005			Revision Date: 3/16/2015	
Part Name:	Crank Handle				
Material:	Aluminum Round Stock (1/2" D)				
Quantity	1				
Step #	Process Description	Machine	Fixtures	Tool(s)	Speed(RPM)
1	Cut part to length	Bandsaw			
2	File all edges and corners			File	
3	Find datum lines for Y and Z	Lathe		Facing tool	<1600
4	Face part to size, taking .05" per pass	Lathe		Facing tool	<1600
5	Centerdrill hole in end	Lathe		Drill chuck, centerdrill	<600
6	Drill hole in end, 1" deep	Lathe		Drill chuck, #7 drill bit	<600
7	Tap screw hole	Lathe		Drill chuck, dead center, 1/4-20 tap and handle	
8	Deburr all holes, file all edges			Deburr tool, file	

Figure B.3: Drawing for Crank Handle

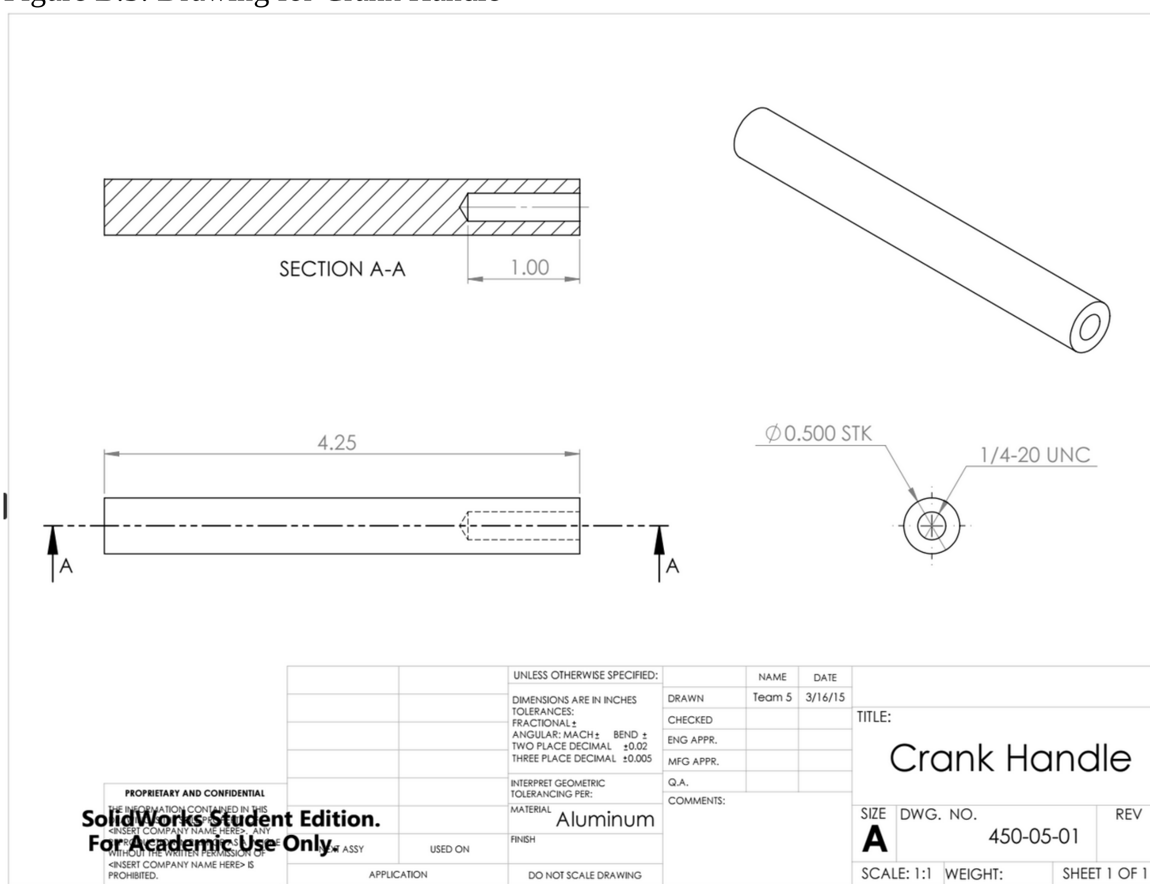


Figure B.4: Manufacturing plan for Crank Handle Sleeve

Team Number:	ME450-005	Revision Date: 3/19/2015
Part Name:	Crank Handle Sleeve	
Material:	Delrin Round Stock (1" D)	
Quantity	1	

Step #	Process Description	Machine	Fixtures	Tool(s)	Speed(RPM)
1	Cut part to length	Bandsaw			
2	Find datum lines for Y and Z	Lathe		Facing tool	800
3	Face part to size, taking .05" per pass	Lathe		Facing tool	800
4	Centerdrill hole in end	Lathe		Drill chuck, centerdrill	800
5	Drill hole in end, thru all	Lathe		Drill chuck, 17/32" drill bit	800
6	Deburr all holes, file all edges			Deburr tool, file	

Figure B.5: Drawing for Crank Sleeve

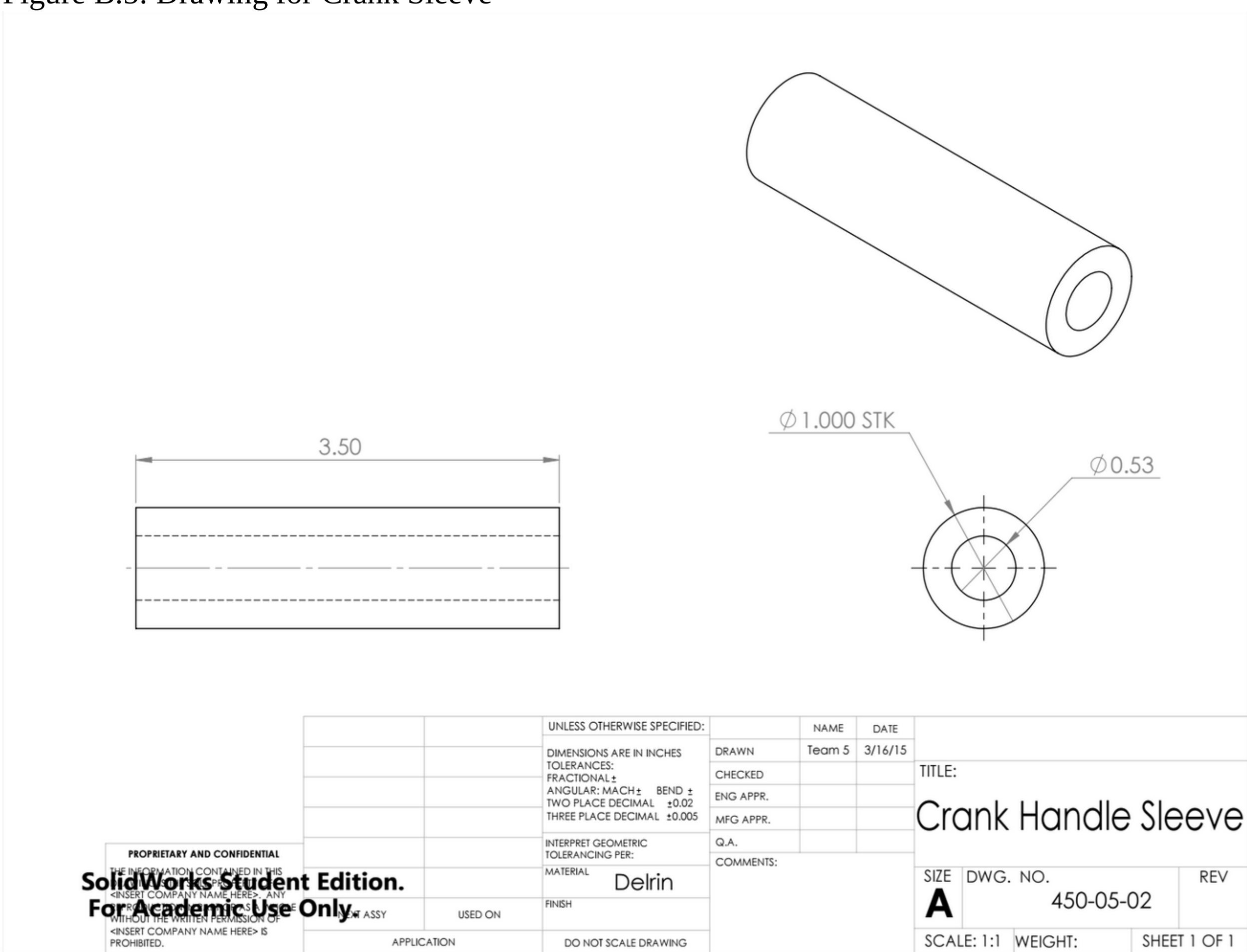


Figure B.6: Manufacturing plan for Crank Arm

Team Number:	ME450-005			Revision Date: 3/16/2015	
Part Name:	Crank Arm				
Material:	Aluminum Flat Stock (1/2" thick)				
Quantity	1				
Step #	Process Description	Machine	Fixtures	Tool(s)	Speed(RPM)
1	Cut part to size	Bandsaw			
2	Find datum lines for X and Y	Mill	Vise	Drill chuck, edge finder	<600
3	Mill the part to size, taking .05" per pass	Mill	Vise	Drill chuck, 3/4" 2-flute	<600
4	Centerdrill shaft hole and handle hole	Mill	Vise	Drill chuck, centerdrill	<600
5	Drill shaft hole	Mill	Vise	Drill chuck, 1/2" drill bit	<600
6	Drill handle hole	Mill	Vise	Drill chuck, 31/64 drill bit	<600
7	Ream handle hole	Mill	Vise	0.4990" reamer	<100
8	Flip part on its side		Vise		
9	Find datum lines for X and Y	Mill	Vise	Drill chuck, edge finder	<600
10	Centerdrill screw hole	Mill	Vise	Drill chuck, centerdrill	<600
11	Drill screw hole	Mill	Vise	Drill chuck, 3/16" drill bit	<600
12	Deburr all holes			Deburr tool	
13	Press Crank Handle into reamed hole	Arbor press			

Figure B.7: Drawing for Crank Arm

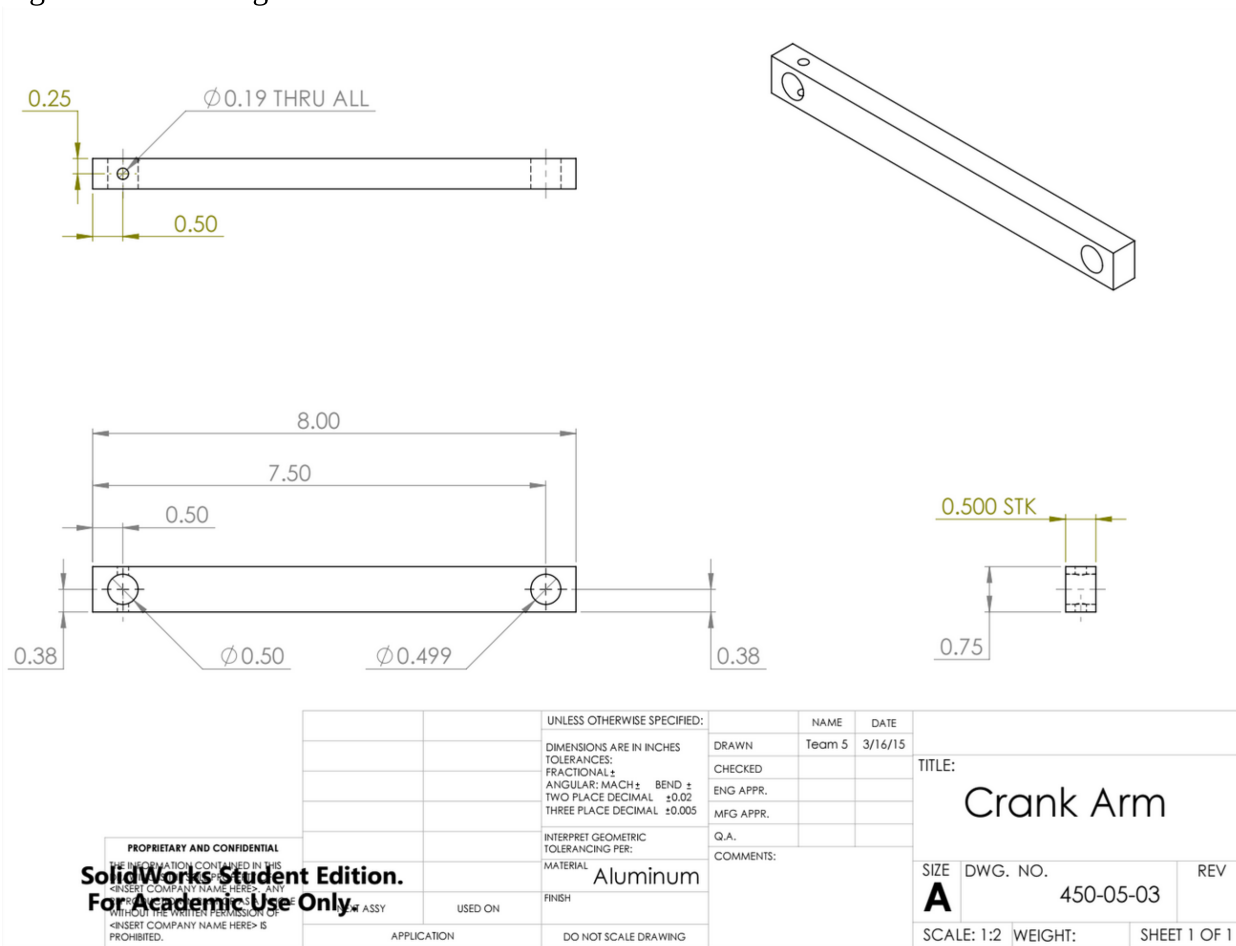


Figure B.8: Manufacturing plan for Hopper Side A

Team Number:	ME450-005			Revision Date: 3/25/2015	
Part Name:	Hopper A Side				
Material:	Annealed Aluminum Flat Stock (1/16" thick)				
Quantity	2				
Step #	Process Description	Machine	Fixtures	Tool(s)	Speed(RPM)
1	Cut out flat shape	Shear			
2	Measure and mark hole locations			Scale, scribe	
3	Centerdrill holes	Drill press	C-clamp	Drill chuck, centerdrill	<600
4	Drill holes	Drill press	C-clamp	Drill chuck, 1/4" drill bit	<600
5	Bend sheet metal	Brake press		Digital level	
6	File all edges and deburr all holes			File, deburr tool	

Figure B.9: Drawing for Hopper Side A

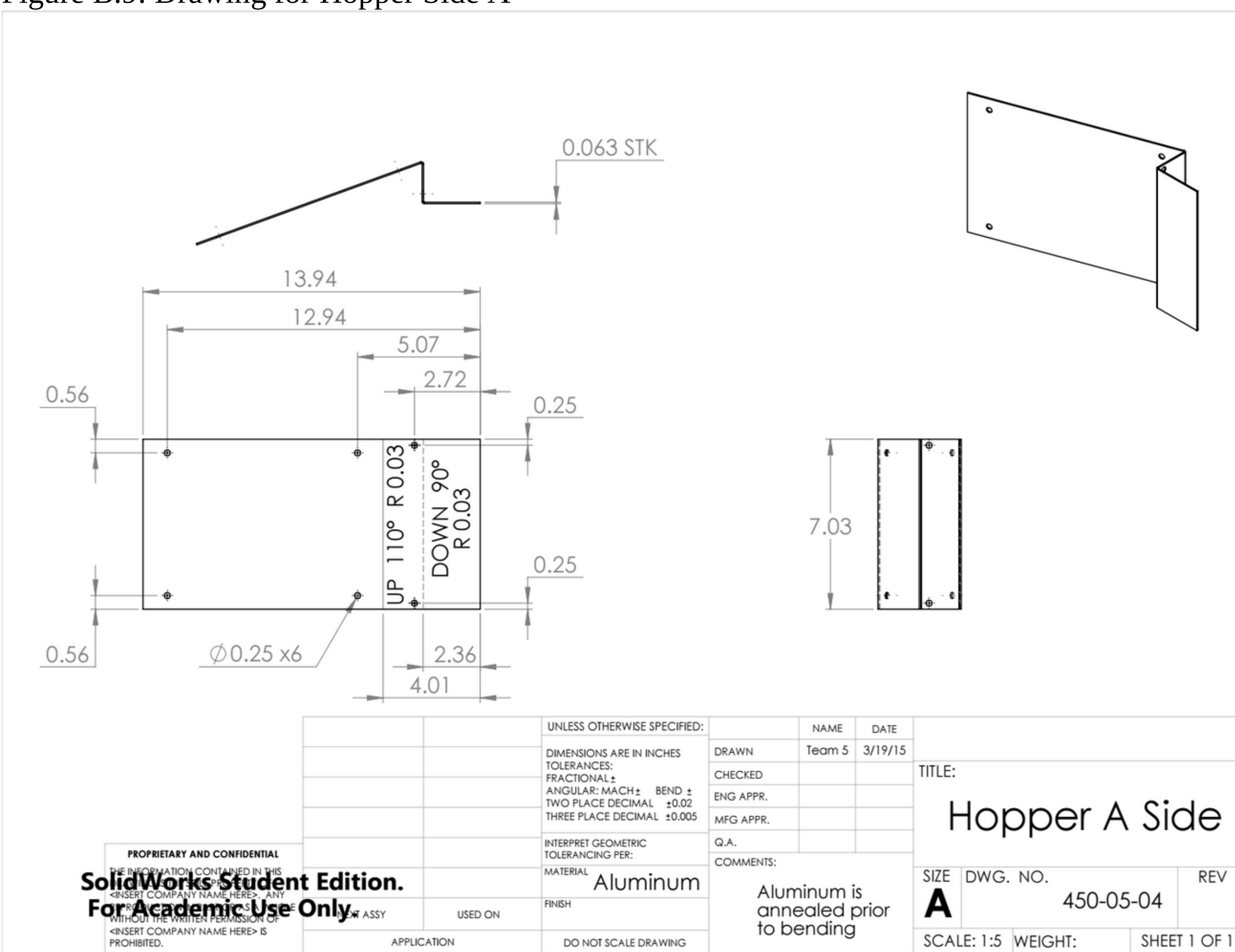


Figure B.10: Manufacturing plan for Hopper Side B

Team Number:	ME450-005			Revision Date: 3/25/2015	
Part Name:	Hopper B Side				
Material:	Annealed Aluminum Flat Stock (1/16" thick)				
Quantity	2				
Step #	Process Description	Machine	Fixtures	Tool(s)	Speed(RPM)
1	Cut part out of the sheet metal	Waterjet			
2	Measure and mark hole locations			Scale, scribe	
3	Centerdrill holes	Drill press	C-clamp	Drill chuck, centerdrill	<600
4	Drill holes	Drill press	C-clamp	Drill chuck, 1/4" drill bit	<600
5	Bend sheet metal	Brake press		Digital level	
6	File all edges and deburr all holes			File, deburr tool	

Figure B.11: Drawing for Hopper Side B

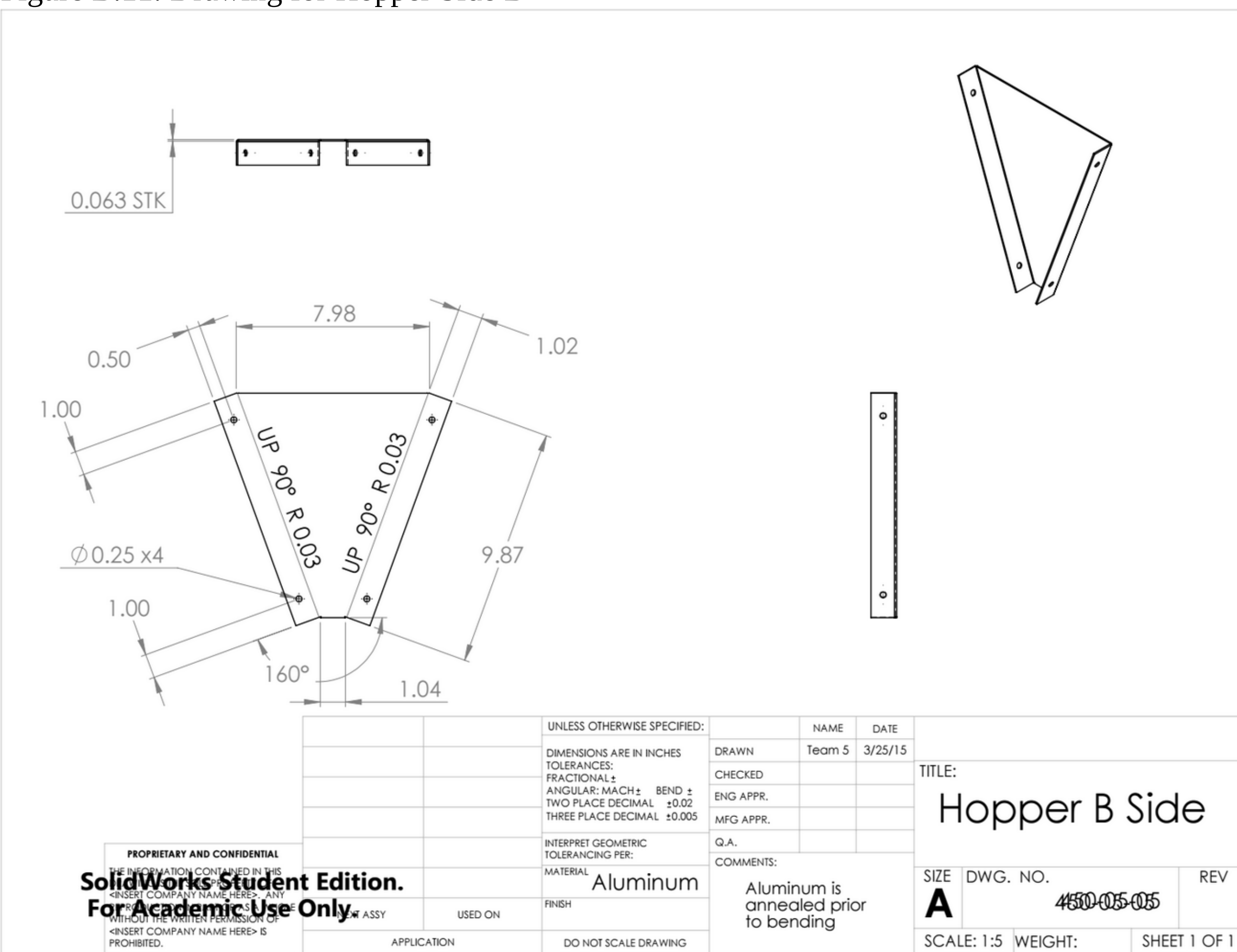


Figure B.12: Manufacturing plan for Base Plate

Team Number:	ME450-005	Revision Date: 3/16/2015
Part Name:	Baseplate	
Material:	HDPE Plastic Cutting Board	
Quantity	1	

Step #	Process Description	Machine	Fixtures	Tool(s)	Speed(RPM)
1	Cut part to size	Bandsaw			
2	Find datum lines for X and Y	Mill	Vise	Drill chuck, edge finder	1200
3	Mill the part to size, taking .05" per pass	Mill	Vise	Drill chuck, 3/4" 2-flute	1200
4	Centerdrill mounting holes and corner of hole for grinder opening	Mill	Vise	Drill chuck, centerdrill	1200
5	Drill corner of grinder cutout	Mill	Vise	Drill chuck, 5/8" drill bit	1200
6	Mill outline of grinder cutout	Mill	Vise	Drill chuck, 5/8" 2-flute	1200
7	Drill mounting holes	Mill	Vise	Drill chuck, 1/4" drill bit	1200
8	Deburr all holes, file all edges			Deburr tool, file	

Figure B.13: Drawing for Base Plate

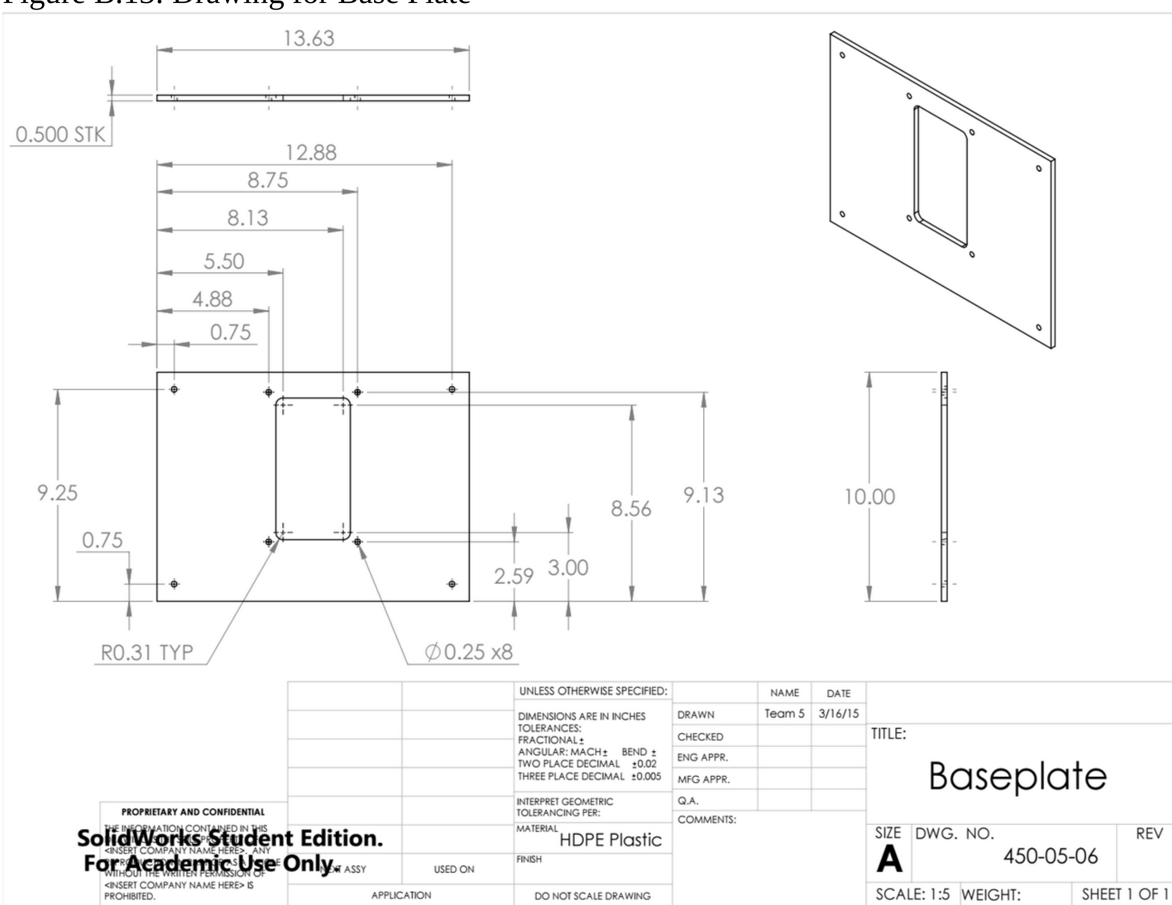


Figure B.14: Manufacturing plan for Strainer Rim

Team Number: ME450-005 Revision Date: 3/26/2015

Part Name: Strainer Rim

Material: Clear Acrylic (1/4" thick)

Quantity 1

Step #	Process Description	Machine	Fixtures	Tool(s)	Speed(RPM)
1	Cut shape out of acrylic sheet	Laser cutter			
2	Glue to strainer			Hot glue gun	

Figure B.15: Drawing for Strainer Rim

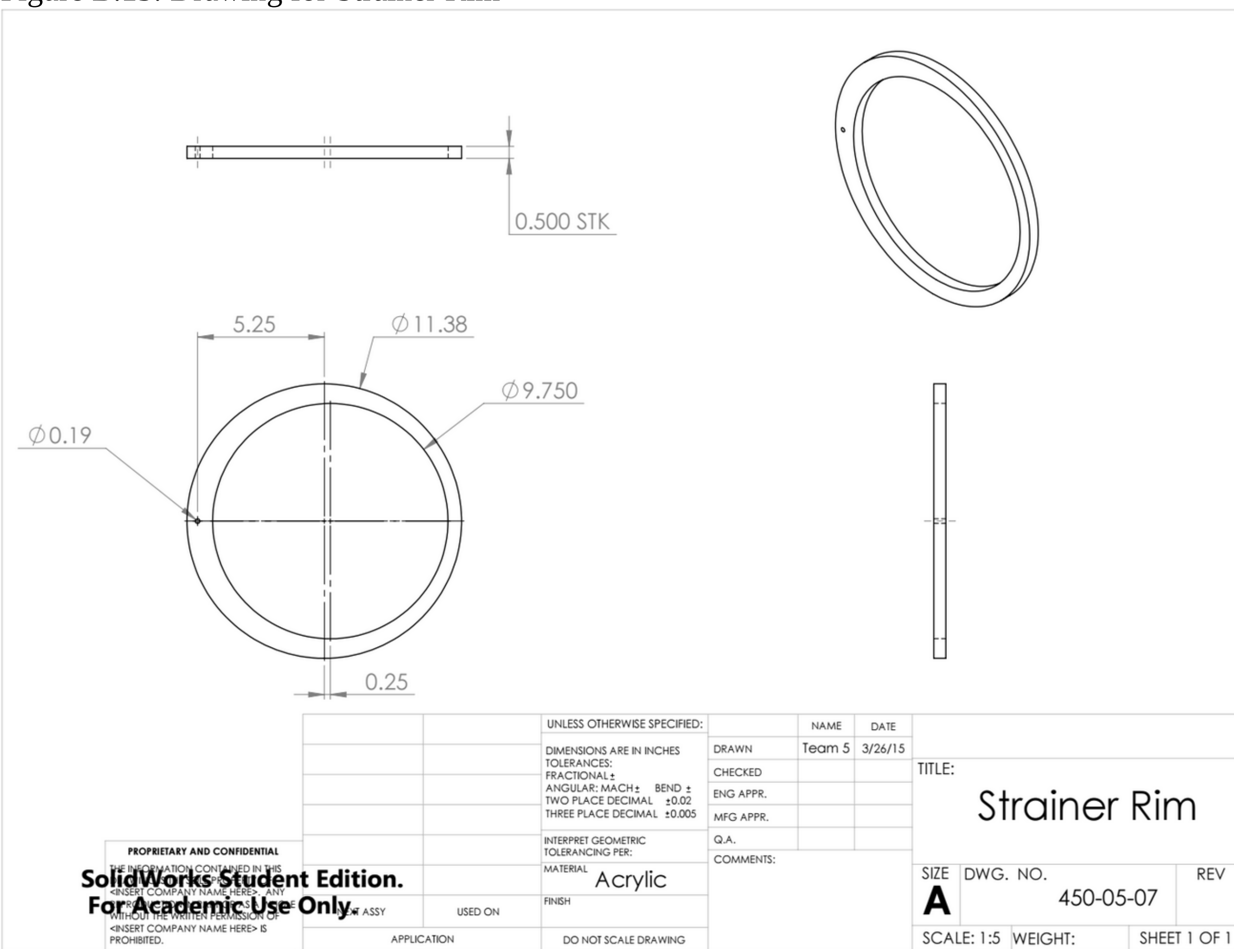


Figure B.16: Manufacturing plan for Baseplate Extension

Team Number:	ME450-005			Revision Date: 4/10/2015	
Part Name:	Baseplate Extension				
Material:	Clear Acrylic (1/2" thick)				
Quantity	2				
Step #	Process Description	Machine	Fixtures	Tool(s)	Speed(RPM)
1	Cut shape out of acrylic sheet	Laser cutter			

Figure B.17: Drawing for Baseplate Extension

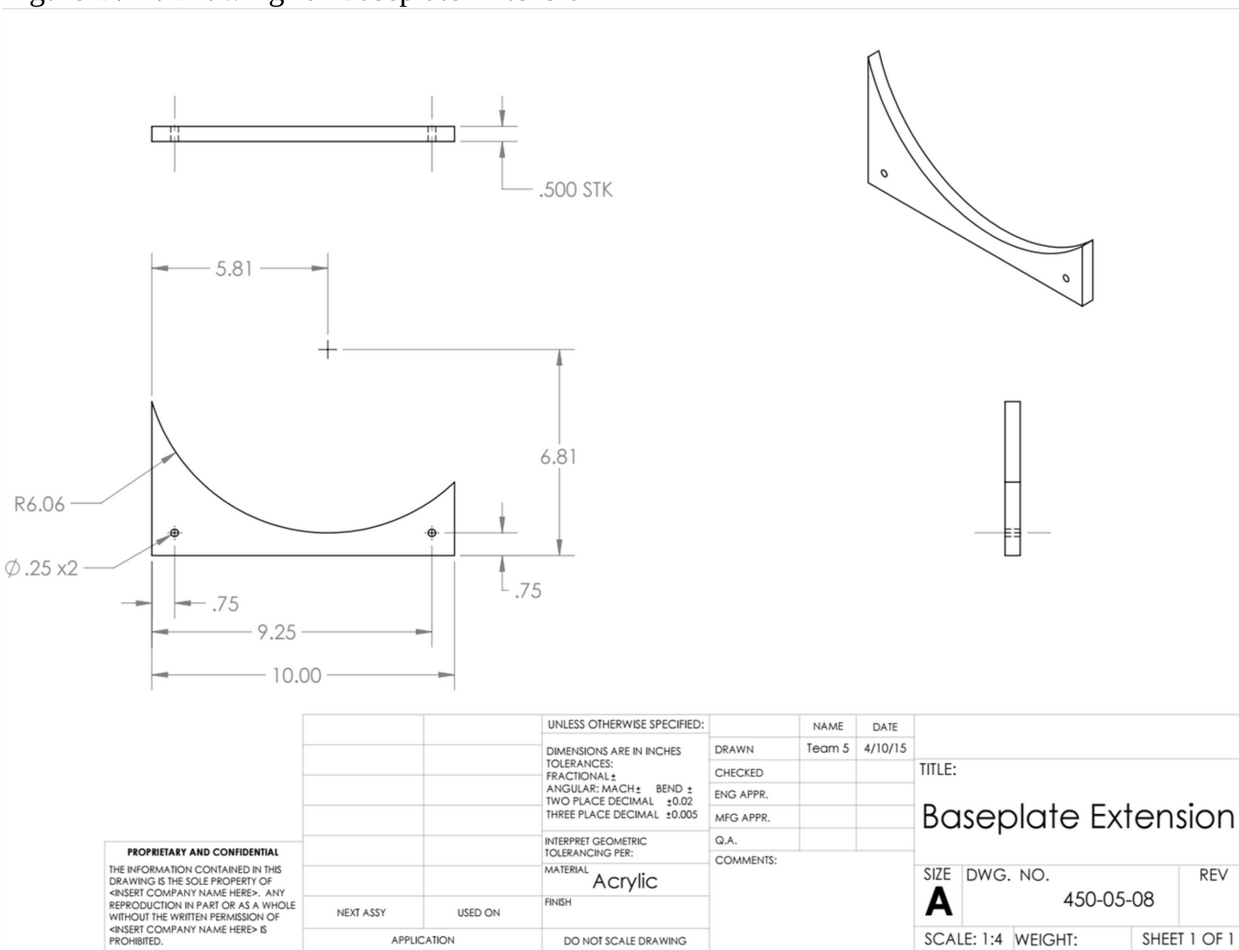


Figure B.18: Manufacturing plan for Gap Blocker

Team Number:	ME450-005			Revision Date: 4/10/2015	
Part Name:	Gap Blocker				
Material:	Deltrin Flat Stock (1/4" thick)				
Quantity	2				
Step #	Process Description	Machine	Fixtures	Tool(s)	Speed(RPM)
1	Cut part out of flat stock		Vise	Hacksaw	
2	Glue to roller assembly			Silicone glue	

Figure B.19: Drawing for Gap Blocker

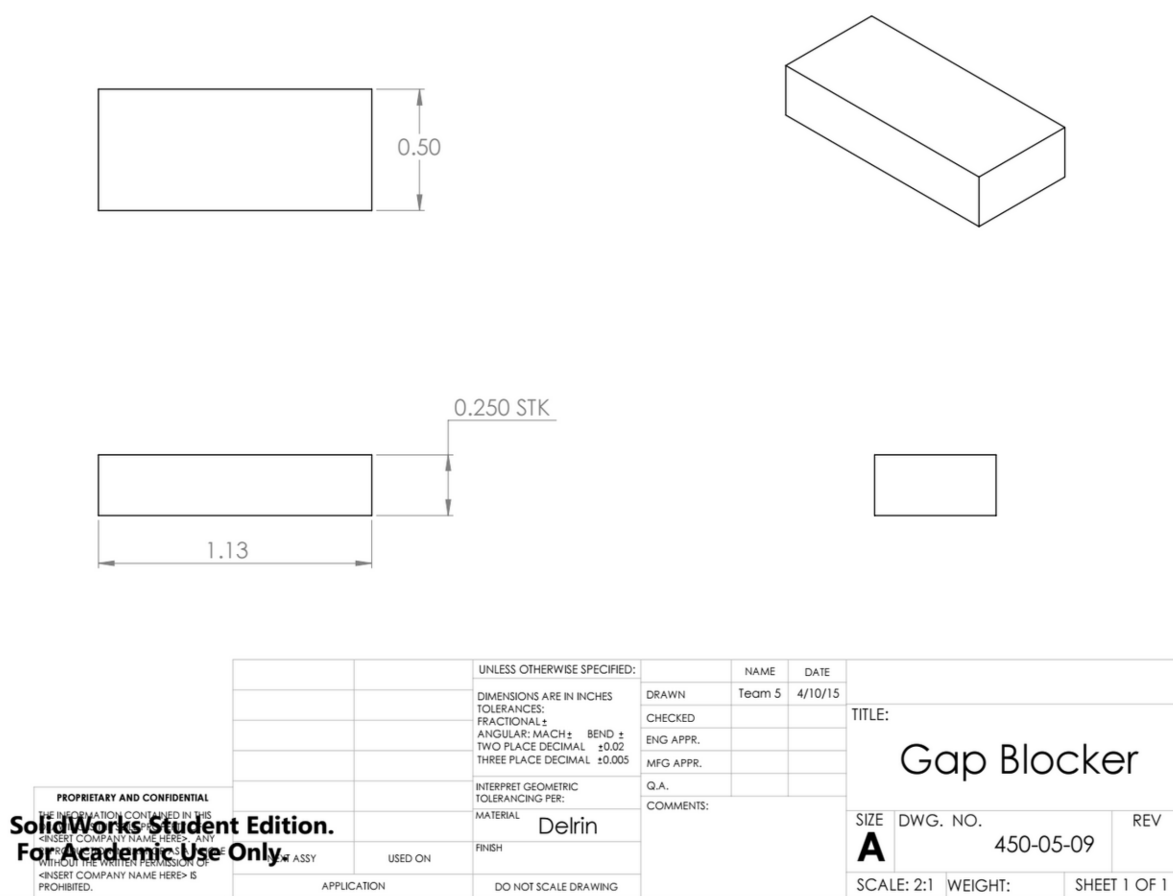
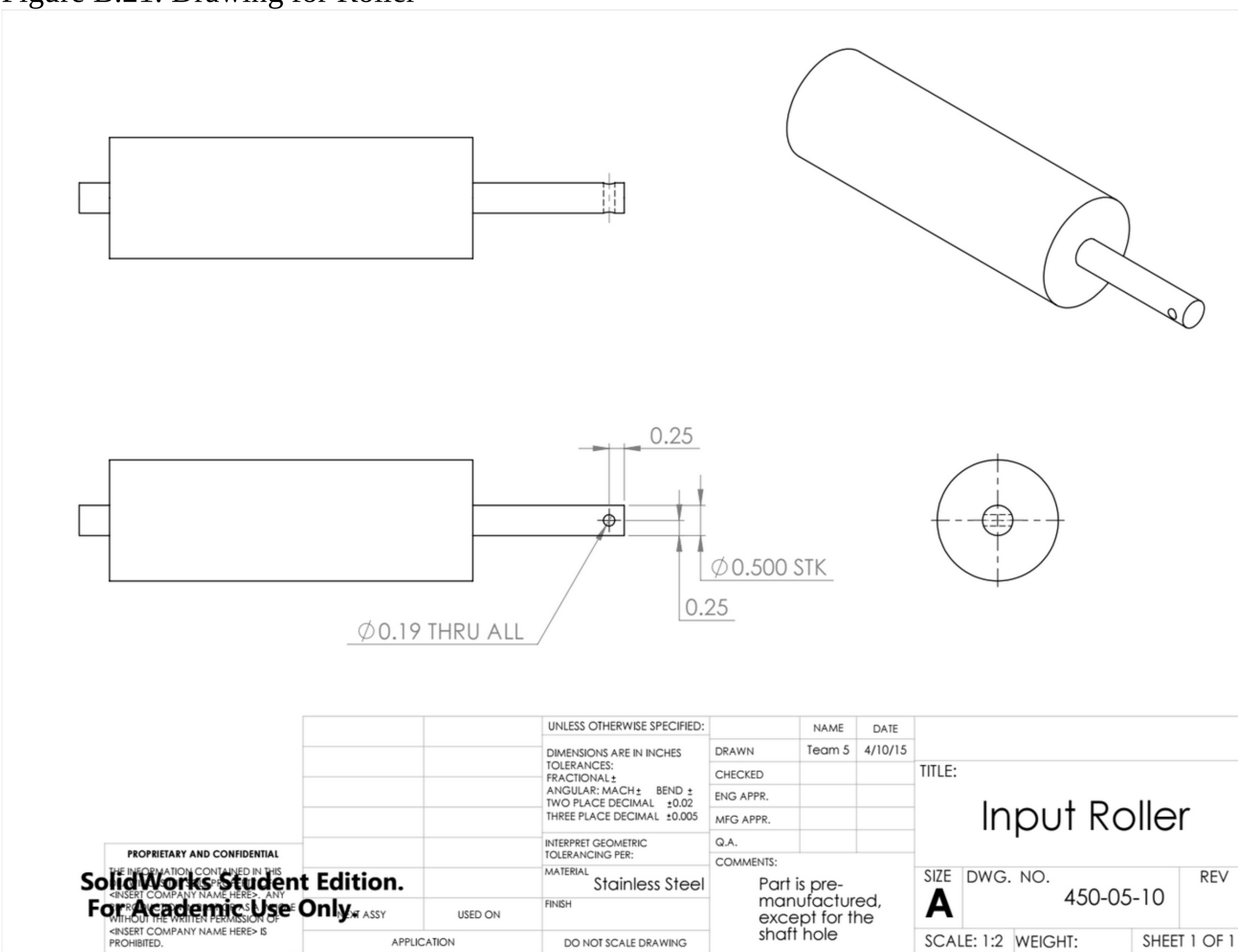


Figure B.20: Manufacturing plan for Input Roller

Team Number:	ME450-005			Revision Date: 4/10/2015	
Part Name:	Input Roller				
Material:	303 Stainless Steel Input Roller (Monster Mill)				
Quantity	1				
Step #	Process Description	Machine	Fixtures	Tool(s)	Speed(RPM)
1	Find datum lines for X and Y	Mill	Vise	Drill chuck, edge finder	<850
2	Centerdrill hole	Mill	Vise	Drill chuck, centerdrill	<850
3	Drill hole	Mill	Vise	Drill chuck, 3/16" drill bit	<850

Figure B.21: Drawing for Roller



Appendix C

Category: Breadfruit flour production
Protocol: Device was tested through numerous grinding processes using dried potato pieces as a substitute for breadfruit. We took note of the specific gap size needed for different potato particle sizes for every iteration, and the number of iterations needed to achieve 80% or more particles passing through our 0.1mm-grade mesh strainer
Result: A total of 8 iterations reduced the potato particles to a size that passed the 80% mesh strainer requirement without fail every time

Category: Safe and edible flour
Protocol: Checked the metals used in the design, and rigorously examined the resulting flour for any contaminants
Result: 303 stainless steel rollers are confirmed food grade metals, and produced no metal shavings in any of the resulting flour batches

Category: Overall safety for user
Protocol: Checked the completed design and examined for any openings greater than a ¼" and made sure it could not come in contact with any moving parts. We also had random individuals use the machine to make sure it was safe for a range of ages.
Result: We ensured there were no gaps big enough to stick a finger through and after testing from ages of 10 years old and upwards of 60 years old, we were able to ensure safe operation with no injury.

Category: Manual energy: required torque
Protocol: Using a force gauge, we attached it to the handle of the grinder to determine how much force it would take to do a pass of dried potatoes of various sizes through the rollers.
Result: After multiple tests, we concluded the torque needed ranges from 8.75ft*lbf - 17.5ft*lbf to run the dried potato through the rollers. Referring to a Canadian Centre for Occupational Health and Safety article, the recommended upper force limits for horizontal pushing and pulling is 24 ft*lbf. Our values lie under this recommended limits and allows us to believe the manual energy needed to run the grinder will be at a safe limit for users.

Category: Easy to clean
Protocol: After running grinder with the dried potato, we tested to determine how long it would take to clean the entire assembly.
Result: Average of approximately 5 minutes 20 seconds to wipe down the hopper and bucket with a dry towel and clean the rollers with some water and a toothbrush. Successful cleaning and all shreds and dust were cleared off.

Category: Ease of assembly and disassembly
Protocol: Random individuals were selected to assemble and/or disassemble the grinder under timed setting using the provided tools and manual
Result: Average of approximately 12 minutes and 19 seconds was needed for an unfamiliar individual to correctly assemble and/or disassemble the grinder, which is well below our user requirement of 20 minutes

Category: Size and weight
Protocol: For size validation, components were disassembled and positioned to test whether or not containing all of them inside the 5 gallon bucket is feasible. Then, the fully assembled device was weighed using a scale
Result: We have determined the optimal way to fit every component and necessary tool required for assembly inside the standard 5 gallon bucket without putting major strain on any of them. The total weight of the device is 21 lbs, which is well below our engineering requirement of 50 lbs.

Appendix D

Steve's Individual Section:

Ethical Design

In addition to designing a breadfruit grinder to best meet our specifications, our team has ensured that the finished product meets the American Society of Mechanical Engineering (ASME) Code of Ethics. We always prioritized safety first with our grinder. While the abrasive rollers present a danger to the operator, we have designed the hopper and baseplate to protect the user's hands and fingers from injury. Additionally, the material selection was important with our grinder. We originally tested the grinding with 1144 steel rollers; however, we later deemed these unsafe for our final device after they rusted while we were cleaning them in 94% isopropyl alcohol. Although the 303 stainless steel rollers cost us an additional $80, they were purchased because it was the right thing to do.

Problems like this may seem like a hindrance to the design process, but in fact they play a crucial role in it because they allow us to catch these issues ahead of time and minimize any negative impact. While we had a $400 budget to work with, we tried to minimize the cost of the grinder as much as possible without sacrificing any integrity. We did this because we wanted to create a device that could easily be replicated by others and distributed among communities in Haiti. Shaving even a few dollars off the final cost means a lot to our end users. Furthermore, our grinder was designed to fit into its environment with the materials and tools available in Haiti. We minimized the number of custom parts that need to be manufactured remotely and then shipped down. The bucket and baseplate could easily be replaced with objects available to the communities, meaning that new parts would not need to be purchased and shipped there if one of them were to be damaged. Similarly, all bolts and nuts were standardized so only a few common tools are needed. We replaced the two gap size adjustment screws that came with the Monster Mill rollers with thumb screws that can easily be adjusted by hand. This will save the user a lot of time and hassle when he or she has to reduce the gap size with each iteration of grinding. We thought it was unethical to have a device like ours not be able to help the community because special tools were not available to the user.

Our team did not adhere to the Code of Ethics just to avoid legal issues with our grinder's end users; rather, we maintained high moral practices because we truly want our device to enrich people's lives, not hurt them. Any potential danger that we foresaw in the design and testing process was avoided to make our grinder as safe as possible. We did not take any shortcuts throughout our design process, and we have maintained complete honesty and transparency with the problems that have arisen along the way. We are all confident that our breadfruit grinder will enrich the lives of its users and that we would feel safe operating the grinder ourselves.

Environmental Impact Statement

Our team has deeply considered the environmental impact of our breadfruit grinder. Although this was not one of our sponsor's requirements, we felt that it was the right thing to do as an engineer. There will be no emissions of greenhouse gases since our breadfruit grinder is manually powered. On the other hand, the materials chosen for this device are the products of a lot of energy-intensive machinery. We had to use stainless steel for our rollers since they needed to withstand the humid climate in Haiti, and rust would cause serious health issues with anyone who eats the flour. However, we could have used recycled plastics for our hopper, baseplate, and bucket. We chose to use aluminum and plastics instead in order to minimize costs.

The biggest environmental impact will be from the collective process introduced with our project and RIT's breadfruit projects. The 3-step procedure that will result from our shredder, dryer, and grinder will allow the Haitian communities to reduce their environmental footprint. Preserving breadfruits that normally would have rotted and been thrown out will mean that the flour will be a green, previously-wasted source of food. Furthermore, harvesting food locally will reduce the amount of imports required for the island country, which will have a significant impact by reducing the fuel used to transport food to Haiti.

Finally, we considered the product's end-of-life. The parts are not biodegradable, but they can be repurposed. The grinder itself can be used year-round to mill other goods like coffee beans or nuts. Many of the individual components can be replaced with local materials in the community. For example, if the baseplate breaks or gets damaged, a piece of wood could be used to replace it. The rollers, on the other hand, could be re-sharpened to keep them in use. Although stainless steel is an energy-intensive material, the solid stainless steel rollers can be re-machined and reused for many years.

Our breadfruit grinder could have a smaller environmental footprint if built with different materials; however, the lifestyle change that it introduces has a much greener impact. If this device were to be mass produced, the environmental impact should be thought about more during design.

Paul's Individual Section:

Ethical Design

Because the ultimate objective of our project is to provide an alternative solution to Haiti's self-sustainability regarding food, ethics was of paramount importance in the design process. The American Society of Civil Engineering Code of Ethics states that engineers shall hold paramount the safety, health and welfare of the public and shall strive to comply with the principles of sustainable development in the performance of their professional duties. We, the breadfruit grinder team, are the engineers, and the Haitian farmers and those interested in preserving breadfruit are the public we are striving to serve. Through various design reviews and revising our design over time, our design decisions progressively prioritized the ethics-related repercussions and we all agree that it is the right thing to do.

For instance, the budget strain of $400 has initially convinced all of our team members to purchase a less expensive, 1144 steel grinding rollers. We believed that for the successful fulfillment of our engineering requirements, it was the most prudent thing to do at the time. However, our attempts at cleaning the rollers for any debris from the manufacturing process involving isopropyl alcohol and water proved that the rollers were extremely prone to rust. The inability to clean debris of manufacturing is a critical problem in creating edible flour, but rusting within the 24hour window of exposure to moisture is a problem of a larger scale. It would not withstand the climate of Haiti and the possibility of any rusted steel particles ending up in the flour consumed by Haitians poses a grave health threat. Therefore, as a team we agreed to return and upgrade to a much more expensive 303 stainless steel grinding rollers that are not only corrosion resistant, but also food grade. This has made our design project a little more difficult by tightening the budget—however, we did not look back once on the decision for our duty is not to complete the course in the most convenient way, but to actually produce a prototype of an idea that can safely help the Haitians to a better state. The change we are making to the breadfruit scene in Haiti may be extremely small; however, any and all potential hazard should never be overlooked.

Last but not least, we have designed the feeding system of the grinder so that it is not only easy for the user to operate the machine, but also difficult for anyone to injure himself/herself during its operation. The hopper (funnel) is just tall enough so that putting in dried breadfruit is easy when standing up, but it is difficult for person operating the hand crank to be anywhere near the abrasive grinding rollers.

In sum, we are confident that we have taken into account the safety and wellbeing of our end user. We have not forgotten the importance of ethics in producing a prototype that aims to affect people's lives and thus any and all possible problems were not overlooked or taken lightly.

Environmental Impact Statement

I believe that the scope of our project—the objective we are striving towards and the impact we wish to bestow upon the target users—incorporates the environmental footprint in a very significant way. First of all, we and the students from RIT are tackling the issue of limited shelf life of breadfruit so that not only will more people have access to the abundant food item that is breadfruit, but also prevent most of the harvested fruit from being wasted. If shredding, drying and grinding breadfruit becomes more of a popular, widespread and refined technique in Haiti, it has the potential of reducing Haiti's dependence on imported foods—food items that may be energy intensive to produce and transport. Second of all, unlike many grinding machines that industrial food manufacturers use here in the United States, our design is intended for a semi-permanent implementation that takes advantage of manual-powered operation. Although the scale of flour production is not comparable, the benefit of going this route is the minimization of the environmental footprint (e.g. no greenhouse gases emission from operating the machine) and independence from electricity.

Regarding the choice in the materials that we have used, the grinder consists mostly of machined metals. The grinding rollers are manufactured out of 303 stainless steel, and the hopper (or funnel) is manufactured from sheet aluminum. I believe that using metals as such was a more environmentally friendly method, for metals can be more easily recycled or repurposed by the end users should they wish to do so. I am aware of how energy intensive it is to manufacture grinding rollers out of solid stainless steel. It is very likely that Monster Mills Inc. that we purchased them from uses heavy machinery for machining them to the appropriate specifications. However, we justified the purchase for our primary goal is to build a machine that will not only survive the humid and hot environment of Haiti, but also produce flour that is edible and harmless at any given time of operation.

At our grinder's 'end of life,' I can see many of the components being repurposed. For example, aluminum and steel are very versatile metals, so the end users or those who are interested can machine them into components of other machines. Also, other main components such as the multipurpose bucket and the kitchen sieve can be used in many applications as standalone items. As a result it can be said that our grinder is designed so that none of its key components need to be discarded during or even after its life.

Dave's Individual Section:

Ethical Design

Our breadfruit grinder is the third phase in a process that is designed to convert breadfruit pulp into flour to significantly increase its shelf life. In addition to performing this task our device must also meet the American Society of Mechanical Engineering (ASME) Code of Ethics. Our primary ethical concern in regards to our project was safety. The Breadfruit grinder is required to operate with minimal risk of injury and produce Breadfruit flour that is safe for consumption. The rollers needed to be clear of any metal shaving remnants from the initial machining process and made of material that would not wear from extended use. This wearing could result in additional metal flakes being produced and mixed with the resulting flour.

Food grade 1144 steel rollers were initially chosen for this task, but were found to rust when exposed to isopropyl alcohol during the cleaning process. Given these results and the knowledge of Haiti's humid environment it was determined that our rollers were likely to rust in that environment and would not be suitable for handling food. We decided that higher grade and consequently more expensive 303 Stainless Steel rollers would be an adequate replacement, but there was significant concern that we would not receive our replacement rollers in time for the design review #5 deadline. This concern was later proven to be true which meant that we were unable to fully demonstrate the grinding capacity of our prototype during DR5. While this was a setback we were glad that we were the ones to discover this flaw rather than our intended users.

We also designed the device around ease of use, protection from injury, and replacement of parts. The device itself is fairly simplistic in its operation and assembly. A detailed instruction manual will be provided that walks the user through the assembly and operation processes. The Breadfruit feeder itself is designed to block hand access to the rollers near the base plate as well as through the top of the feeder itself. This is in an effort to prevent hand injury due to the rollers. The parts used in the manufacture of this device, with the exception of the rollers themselves, were chosen in a way that would allow local villagers to easily replace them with parts readily available in Haiti. Given the inclusion of these safeguards and features I would be perfectly comfortable recommending use of this device to anyone.

Environmental Impact Statement

In recent years products have been increasingly designed around environmental impact and sustainability. Three of the main categories focused on when gauging environmental impact are product manufacture, use phase, and end of life characteristics. By far the most negative environmental impact from our device occurs during the manufacturing process. Large amounts of energy which is derived from coal and natural gas is expended to produce the stainless steel and aluminum components that comprise our grinder. This process of machining metals results in large amounts of carbon dioxide being produced. This is difficult to avoid given the current methods of energy production in the United States, but can be minimized by building long lasting quality products. With this in mind we have designed a device that should last several harvest seasons requiring minimal part replacement or re-manufacture.

Based on our project requirements of designing a device that does not require electricity we have designed a device that is purely mechanical. It is hand powered and requires no additional energy sources. This was in an effort to combat Haiti's unreliable power grid as well as make the device useable anywhere. Given the nature of the device's operation it has a zero carbon footprint during the use phase.

The device has a relatively good standing in regards to its end of life characteristics. The stainless steel rollers, aluminum feeder and crank handle, plastic base plate, plastic bucket, and strainer can be recycled. Unfortunately it is unlikely that Haiti has adequate facilities to carry out this process which will most likely result in these materials being discarded in a landfill. The recycling process itself can be fairly energy intensive, but it removes the need for costly manufacture of new materials. Replacement parts for everything, but the rollers should be easily obtained locally which will also cut back on environmental impacts.

Jason's Individual Section:

Ethical Design

As a team we have applied the Code of Ethics to the design process of our breadfruit grinder. Our grinder will help with preserving their fresh fruit and produce flour to allow for food throughout the entire year. The grinder must be able to run without harming the individual and the flour produced needs to be edible and safe for people to ingest.

In the American Society of Civil Engineering (ASCE) code of ethics, one of the ethics state: Engineers shall hold paramount the safety, health and welfare of the public and shall strive to comply with the principles of sustainable development in the performance of their professional duties. In our case, we are creating this for public so it is important we meet the requirements and ensure health of public. We ensured this was met by purchasing the rollers that grinded the breadfruit into flour to be food grade. The design now implements rollers that are produced from 303 stainless steel. 303 SS is corrosion resistant to atmospheric exposures, sterilizing solutions, most organic and many inorganic chemicals; most dyes, nitric acid and foods. This choice was unanimous among our group to choose a high grade roller. Other metals we could have used were aluminum and non-stainless steel which is either respectively softer metal and cause for aluminum flakes to fall into the flour or prone to corrosion under humid conditions.

Under the same code of ethics, safety of the public is also paramount. When operating the grinders, the grinding surfaces must be contained and not exposed so fingers cannot be caught and injured. We made sure our contraption is covered and safe while the rollers are running. We also had to consider how the user operates the machine. We want to make sure long-term use of the grinder will not harm their shoulder or their body. One thing we did was create a suitable handle. To maximize the torque we created a longer handle that will allow for easier use of the machine.

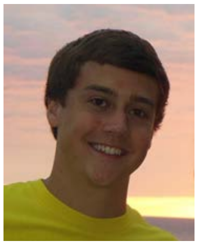
Overall, our team made choices to ensure our final design was safe, usable, and most importantly ethical.

Environmental Impact Statement

Environmental changes and global warming have been hot topics of conversation especially in the past couple years, and as an engineer we have an obligation to build and design having sustainability in mind. As our team created our breadfruit grinder we also thought of about the environmental impacts it would have. First step was limit the number of parts used in our design. When you minimize the parts used, the overall design is simplified which not only makes it more simple to manufacture with less material but also easier to maintain and fix. Secondly is choosing the most suitable material, either one that can be easily recycled or parts that are durable and can be re-used and re-purposed. Thirdly, the optimization of the production techniques minimizing the number of steps needed to produce and producing less waste.

Fourthly, the reduction of impact during use either running on cleaner energy or reduce energy needed. Lastly, the optimization of its initial lifetime as well as its end-of-life use.
For our breadfruit grinder we choose a simple design composed of only five main subsystems: hopper, rollers, base plate, strainer and the bucket. This meets our first requirement of having fewer parts which will result in less material. Each subsystem completes its own tasks and is made of its own material as well. The hopper which is made out of aluminum, the rollers from stainless steel, the base plate from high density polyethylene, strainer from aluminum, and the bucket of plastic. The materials we are using are all common materials that we encounter everyday. This means obtaining the materials is not a difficult task. When we talk about operation, there will be energy needed to run the grinder since it will be hand powered. This will save the environment and thus after production there will no longer be any carbon emissions. Once the grinder surface becomes no longer usable, some of the parts can be re-purposed. The bucket can be re-purposed for collecting materials or water and the base plate can be used as a cutting surface. Overall, the grinder does not have a huge environmental impact once it is built but with smart choices of material and manufacture methods the grinder the breadfruit grinder is even made more sustainable.

Authors



Steve Barch is a senior in Mechanical Engineering. He is interested in sustainability and renewable energy. He has previously held internships at Quicken Loans and National Instruments, and he will join the FCG program at Ford after graduation. For four years, he has been actively involved in the UM Polish Student Association. Outside of school, he enjoys listening to music and running.

Paul Choi is a senior majoring in Mechanical Engineering at the University of Michigan. He is interested in fluid mechanics and plans on attending graduate school after graduation. He is currently working for the Naval Engineering Education Center (NEEC) sponsored by the United States Navy in investigating underwater reverberations and acoustics in general. Outside of school, he likes to travel and enjoys watching films.

David Durm is a senior in Mechanical Engineering. His degree focus is sustainable and renewable energy applications. His previous work experience consisted of piloting Unmanned Aerial Vehicles (UAVs) for the United States Army. He is actively seeking employment and plans on working for companies in the field of renewable energy. Outside of school he enjoys traveling, skiing, running, and kayaking.

Jason Liu is a senior in Mechanical Engineering at the University of Michigan with a minor in the Program of Sustainable Engineering. For four years, he has spent much time working with professors in research, most recently working on obtaining ignition delays of combustion engines while running on various types of fuels. He has previously held an internship with Dow Corning and will join the EDGE program at Dow Chemical in New Orleans starting in August 2015.

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