Rural Food Processing

Final Proposal

Humoud Alanjari
Musab Albalool
Nygel des Vignes
Samantha Morrison

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Project Sponsor: W.L. Gore and Isaac Zama
Mentor: Chuck Vallance
Instructor: Sarah Oman

DISCLAIMER

EXECUTIVE SUMMARY

The dish Ekwang features ground cocoyam that is rolled inside of cocoyam – or other types of – leaves. This process is time-consuming and labor intensive as it is currently performed almost entirely by hand. After grinding, it requires individuals to manually dispense cocoyam onto leaves which are taken by hand and slowly wound up tightly where they will then be cooked. The project presented by Isaac Zama, a humanitarian, was to create a device that will reduce the time requirement of the rolling process by allowing for automation of the process through a simple and easily manufacturable design.

Through conversations with the client, mentor, and within the team, the team was able to determine a set of customer and engineering requirements. The most important customer requirements determined were reliability, safety, simplicity, and that the design is faster than the current hand rolling process. The most important engineering requirements determined were factor of safety, cost, and minimizing the time required to produce one roll.

From these requirements, the team determined initial designs. As the semester progressed, conversations with the client assisted in shaping the overall design of the system. The system is composed of two main subassemblies: the dispenser and the roller. The dispenser is just three components which hold the cocoyam and pushes it out a nozzle. The roller is mainly a base with a roller bar that is connected to a handle. The roller bar is fed through two side rails that assist with the direction of motion. Connected to the roller bar and the base is a belt which is also partially forced through a gap towards the end of the roller base.

The dispensed cocoyam is placed on one end of the roller by the handle. The handle is advanced forward to the opposite end which wraps the belt as it progresses. This motion causes the leaf to roll onto itself as the system is advanced. Once the cocoyam is completely rolled, the positioning of the gap in the base allows for the rolled cocoyam to fall through to prevent unravelling. The handle is then pulled back toward the user and the final rolled product remains in the gap, allowing for removal by the user.

Through prototyping, the team anticipates moving forward with the current design and making modifications as needed in order to improve upon the device. Of the $1500 total budget, under $100 has been used for the current prototype as well as being anticipated to use in the next iterative prototype. The team anticipates using upwards of $500 for prototype development using mainly the method of 3D printing for rapid prototyping.

The final design will be an iteration of the current design and will be created from materials similar to those that are available in Africa, as well as using processes that are also available. The team anticipates adhering to the current schedule to allow for early progress toward deliverables. The team ultimately plans to deliver the highest quality end product to the client in order to help communities in West and Central Africa.

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1 BACKGROUND

1.1 Introduction

The project titled "Rural Food Processing" will be designed and created by Team 16 as part of NAU's senior capstone program. The project design includes a simple raw cocoyam dispenser and roller that are both reliable and safe for daily use in the creation of Ekwang meals. The project aims to be a continuation of the manual grinder of cocoyam completed by a different senior capstone team from Georgia Tech last year.

Figure 1: Raw Cocoyam [1]

Raw cocoyam, as shown in its un-grated form in Figure 1, is the base ingredient for Ekwang. The grating of the cocoyam is done prior to the introduction of the processing system. The purpose of this project/design is to provide a new alternative method to substitute the current hand-rolling technique used for rolling processed raw cocoyam in leaves by members of rural West and Central African communities. The current hand-rolling method is time consuming and requires effort as it is a process done entirely by hand. The cocoyam dispenser and roller will provide a better alternative that is both quicker and less demanding overall. This will benefit both residents of the rural areas of Africa as well as those living in cities in Central Africa. It will benefit rural residents by allowing for more time to pursue different activities due to less time required for preparing meals. Similarly, it will also benefit those in cities by providing a more efficient method that can reduce electrical costs since this design will require no electricity. This project will also aid in the transfer of this technology to the younger generation in African rural areas, which will help in the creation, sale and spreading of the technology among the members of the community. This will aid the Central African communities by providing a simpler solution in the long-term than the current highly inefficient and demanding method of hand-rolling the cocoyam in leaves.

1.2 Project Description

The following is the original project description provided by the sponsor:

"Grated raw cocoyam, called Ekwang and Kwacoco Bible are staple meals in much of West and Central Africa. Traditionally, this food is prepared by manually grating cocoyam and wrapped in vegetable or banana leave. The process is labor intensive and time consuming. It can take up to 2 hours to grate cocoyam's for a family of five. A few rich people in the cities in Africa and the diaspora have found creative ways to still eat the food by using blenders or juicers to process the food. However, mothers in rural areas still use the traditional manual method of grating the cocoyam's and wrapping it in leaves. Preparing the food takes enormous amounts of time from women in performing other productive activities. There is a need to improve upon the process of preparing the food by designing a simple and affordable system to use to process the food. Such a system will not only help those in the villages with no electricity, but also people in the cities that have roadside restaurant that sell the food. Even the rich people in the cities will still like to use it, since it reduces their electricity consumption from using the blender to make the food. Africans in the diaspora have figured out a way to use aluminum foil to wrap the paste since it is difficult to have leaves here."

2 REQUIREMENTS

The project goal is to create a dispenser and roller for Ekwang to help West and Central African communities. Preparing these meals is labor intensive work. Therefore, our goal is to reduce the time for preparing the food to make sure they can spend time in other areas of life outside of food preparation. This chapter will discuss the requirements of the project.

2.1 Customer Requirements (CRs)

Table 1: Customer Requirements and Ranking

Customer Requirement/importance	Importance Ranking
1. realibilty	3
2. durability	2
3. lightweight	1
4. safe to use	3
5. simplicity	3
6. low cost	2
7. Easy to use by anoyne	2
8. mobility	1
9. faster than hand rolling	3

The customer requirement ranking was based on what the customer wants. The scale of the customer requirement is 1-3, where 3 is the most important requirement. The importance rankings can be seen in Table 1 above. The top customer requirement requirements are reliability, simplicity, faster than hand rolling, and safe to use. The device needs to have high reliability in order to ensure that the workers will be able to produce a roll with every pass through the system. Moreover, the device needs to be simple to use because people in a rural village will be the main operators. Additionally, the device will be manufactured in these communities which have limited resources and tools. Therefore, simplifying the device is the only way to ensure its public utility. The device must also be safe to use for everyone in the community since both children and adults will use the system.

Requirements based on what the customer stated as important but not of the highest consideration have a lower weight in the requirements in Table 1. These include durability, low cost, and easy to use by anyone. The device durability and cost were not as important to the customer as the device will be manufactured with different materials in Africa than what the final design may be created with. Consequently, the durability and low cost will be ultimately determined by the workers in Africa. However, if our design was able to account for the materials and costs of manufacturing in Africa, it would be better for the customer. The ease of use by anyone is a highly important requirement since it should be used by anyone from the community and it should be understood simply. The lowest requirements were based on what the customer deemed as features he would like incorporated. The client would like the device to be lightweight or mobile. The customer explained that the device will be used in almost stationary places such as homes, street. However, the customer says that it would be better if it can be mobile to ensure that it does not get stolen, especially if the device was being used in the street.

2.2 Engineering Requirements (ERs)

Table 2:Engineering Requirements and Target Values.

Customer Requirement/importance	Importance Ranking	Engineering Requirement	low weight	base footprint	volume of material to create device	smooth edges	low price	minimize time to produce one roll	material strength	material density	Low center of gravity	factor of saftey
Target ER values			7 kg	0.125 m^2	0.02 m^3	r=5 mm	$35.00	30 sec	44 MPa	1040 kg/m^3	-	3
Tolerances of Ers			>10 kg	>0.25 m^2	>0.1 m^3	<5mm	>$45.00	>60 sec	<44 MPa	<1040 kg/m^3	-	<3
Testing Procedure (TP#)			5	5	5	1	5	2	3	5	4	5

Low center of gravity targets reliability. Quantifying center of gravity is important to determine whether our design will be reliability. The target goal is to have low center of gravity via solid works to know the actual center of gravity. Then experimental drop and force tests will be applied to find the experimental center of gravity. These tests will ensure that the design is reliable.

Factor of safety targets to quantify the types of fastener that will work on our design without breaking. The target goal is having the factor of safety equal to 3 and a tolerance greater than 3. This factor of safety will ensure that the fastener will not be lose or break due tensile stress.

Low price targets how the price is affected by other customer requirements. The price is mostly affected by simplicity because the simpler the design will lower the manufacturing cost.
The price goal is $35, and the tolerance is to be less than $45. The goal is set to $35 because the lower the price the better. The price goal is lower than our customer price goal because the lower price, the more people will be able to afford the device.

Low weight targets to quantify the mobility of the device. As the weight decreases, the mobility of the device will increase. The goal is to create a design of approximately 7 kg. This weight was determined based on assuming that this device will be carried by kids and adults. Therefore, 7 kg was based on the average weight the team determined would be easy enough for a ten-year-old to carry. The tolerance is set to be less than 10 kg as the upper weight limit.

Minimize time to produce one roll targets to quantify the time it will take to create one roll when compared to the hand rolling process. The goal determined prior to a real-life demonstration was 30 seconds. Material strength's target is to quantify how durable the material is. The goal is to have a strength of 44 MPa. The 44 MPa will ensure that our design is capable of handling high forces. The tolerance is set greater than 44 MPa because the higher the material strength the better volume of material to create device target is to quantify how mobile our device is. Since the materials to be used have not been determined, this may shift.

Volume of material targets the mobility of the device. The goal is 0.02 m^3 of material. The tolerance is set to no greater than 0.1 m^3. Material density targets to quantify how heavy the weight would be and what materials to choose. The goal is 1040kg/m^3 because the material has to be dense enough to withstand the processes. The tolerance is set to greater than 1040 kg/m^3 because the team is unsure what material will be used.

Smooth edges targets to quantify the safety of the device. The goal radius of the design is to have a radius of 5 mm. The team predicts this radius on sharp corners will provide a smoot finish to minimize the danger of cuts on the device. The tolerance is set to greater than 5 mm because as the radius increases, the curvature becomes smoother. Base footprint targets to quantify how much space will the device will occupy. The goal 0.125 m^2. The team deemed this reasonable considering it is a two-stage system but anticipates a vertical orientation for the device rather than horizontal. The tolerance is set to more than 0.25 m^2 because the larger the design, the less mobile the device becomes.

2.3 Functional Decomposition

The goal of the rural food processor is to receive the cocoyam, dispense the cocoyam, and then roll the cocoyam in order to form the proper traditional dish. A black box model was created to show the overall process of turning the cocoyam into the rolled dish through the device. The functional decomposition shows a detailed overview of how the device will achieve the task.

2.3.1 Black Box Model

The black box model presents an input material (bolded solid line), energy (solid line), and signal (dotted line) on the left-hand side. These point to the box which represents the device that is being created to perform the task specified within the box. There is then an output material, energy, and signal which defines the end of the process.

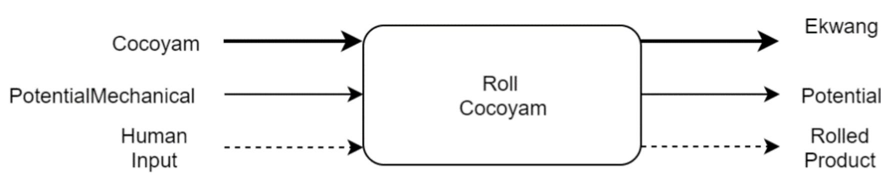

Figure 2: System Black Box Model

Figure 2 represents the overall device inputs and outputs that the team decided were important to the process. However, in contemplating the processes that the system will undergo, the team decided to create a black box for each of the specific actions that the system is comprised of.

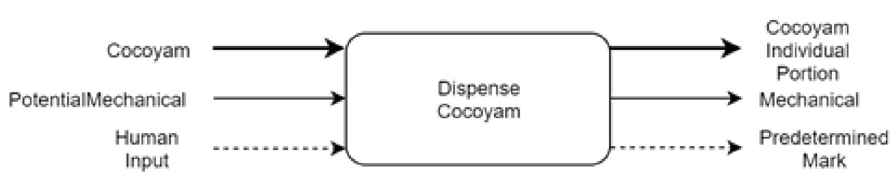

Figure 3: Dispenser Black Box Model

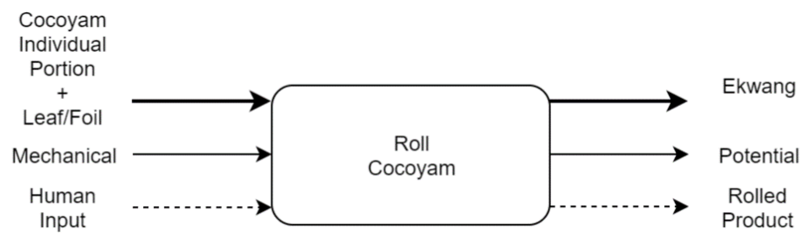

Figure 4: Roller Black Box Model

In the black box models above in Figures 3 and 4, the dispensing of the cocoyam and the rolling of the cocoyam into the final product are split into two distinct black box models. The dispensing process is directly linked to the rolling process because the outputs of dispensing are the direct inputs of the rolling, with the exception of the output signal of the dispensing and input signal for the rolling. By creating these models, the team was more easily able to work towards creating the functional decomposition for the entire system.

2.3.2 Functional Model/Work-Process Diagram/Hierarchical Task Analysis

The team determined that a functional diagram for the project represented in two stages to represent the two subsystems would be the easiest way to define the processes. Moving forward, this decision also drove the team decision to run through concept generation and concept evaluation twice, one for each subsystem, since the final product would be easily combined into the final system.

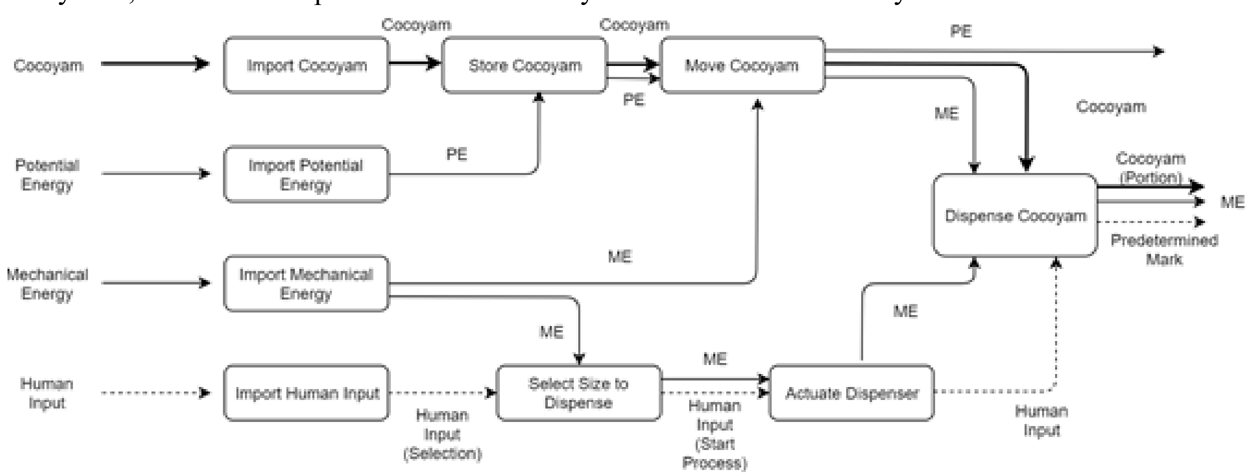

Figure 5: Dispenser Functional Decomposition

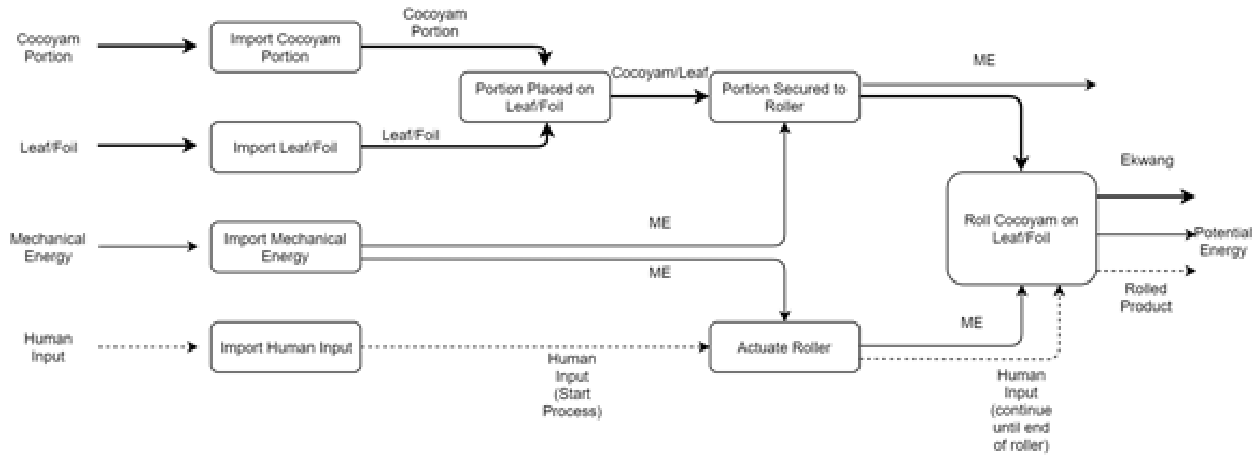

Figure 6: Roller Functional Decomposition

Like in the black box model, the two functional decompositions in Figures 5 and 6 interface as the output of the roller is the input of the roller. The exception is a leaf to house the cocoyam is introduced to the system at the rolling stage, and the initiation for the system is human input with will be the decision to begin rolling by the individual operating the machine.

This model assisted the team in defining where the focus will be in concept generation. By having two distinct subsystems within the project, the team made the decision to complete concept generation and evaluation twice, once for each subsystem. This would allow for the best idea of each to be selected without having too many variants between the systems. The team established that the interfacing of the systems would not be a major concern since the required interface is a direct dispensing of the cocoyam from the dispenser to the roller. By having this established, the team proceeded to generate concepts based on these functional decompositions for each of the subsystems.

2.4 House of Quality (HoQ)

Table 3: House of Quality

Customer Requirement/importance	Importance Ranking	Engineering Requirement	low weight	base footprint	volume of material to create device	smooth edges	low price	minimize time to produce one roll	material strength	material density	Low center of gravity	factor of saftey
1. realibilty	3		1	0	0	0	3	9	9	0	3	9
2. durability	2		3	0	0	3	3	1	9	3	1	9
3. lightweight	1		9	1	9	0	3	0	3	9	0	0
4. safe to use	3		0	0	0	9	0	0	3	3	1	9
5. simplicity	3		1	1	1	0	9	0	0	0	0	0
6. low cost	2		9	3	9	0	9	0	0	3	0	3
7. Easy to use by anoyne	2		1	0	0	0	3	1	0	0	3	0
8. mobility	1		9	9	9	1	0	0	0	3	1	0
9. faster than hand rolling	3		0	0	0	0	0	9	0	0	0	0
Absolute Technical Importance (ATI)			50	19	39	34	69	58	57	33	21	78
Relative Technical Importance (RTI)			11.8	4.1	8.5	7.4	15.1	12.7	12.4	7.2	4.6	17.0
Target ER values			7 kg	0.125 m^2	0.02 m^3	r=5 mm	$35.00	30 sec	44 MPa	1040 kg/m^3	-	3
Tolerances of Ers			>10 kg	>0.25 m^2	>0.1 m^3	<5mm	>$45.00	>60 sec	<44 MPa	<1040 kg/m^3	-	<3
Testing Procedure (TP#)			5	5	5	1	5	2	3	5	4	5

The highest engineering requirements are factor of safety, low price, and material strength as seen in Table 3. Factor of safety was the highest engineering requirement because the device parts need to be connected with screws. Low price is the second most important engineering requirement. Lowering the price is important because it will determine whether people in Africa will be able to recreate the design. However, the price is dependent on other factors such as facto of safety of the fastener. Factor of safety has the second highest importance because the roller will be connected with fastener. Therefore, fastener failure will cause the device to fall apart.

Minimizing the time to produce one roll is the core of the project. However, if the factor of safety for the screw is low the device will fail. Material strength is the fourth ranking in importance to ensure the device will meet the customer requirements of reliability and low weight. However, the device strength will not be exposed a lot of traveling; the main goal for this device is to be used at home. Volume of material is important to ensure that the device is mobile to be moved in villages and directly relates to the mobility customer requirement. Smooth edges are important this device will be used by a variety of ages and will be picked up and moved around. The lowest engineering requirements determined were material density, base footprint and low center of gravity. Ultimately, the main customer requirement and engineering requirements of the new device being faster than the current hand rolling technique, minimizing the time to produce one roll and low-price.

The correlation between customer requirements and engineering requirements were on a 0-1-3-9 scale, where zero is no correlation, one is a weak relationship, three is a moderate relationship, and nine is a strong relationship (Table 3).

2.5 Standards, Codes, and Regulations

Table 4: Standards, Codes, and Regulation and How They Apply to the Project

Standard Number or Code	**Title of Standard**	**How it applies to Project**
ASTM A334/A334M – 04a (2016)	Standard Specification for Seamless and Welded Carbon and Alloy-Steel Tubes for Low-Temperature Service	This standard provides the requirements that alloy-steel tubing must conform to, which our main consideration for materials falls into this category
ISO 7045 (DIN 7985, ANSI)	Cross Recessed (Phillips) Pan Head Machine Screws	Provides requirements for fasteners (screws) that have been selected for use
ISO 7040 (DIN 985, ANSI B18.16.3M)	Stainless Steel Nylon Insert Lock Nut	Provides requirements for fasteners (nuts) that have been selected for use
ASTM UNS S31600	Type 316 stainless steel	Provides material requirements to adhere to stainless steel of 316 type, which is of heavy consideration for use
ANSI Z49.1:2012	Safety in Welding, Cutting, and Allied Processes	Safety is a major concern in use of the product, but should also be a major concern in the manufacturing of the product
AWS B2.1/B2.M-BMG:2014	Base Metal Grouping for Welding Procedure and Performance Qualification	Provides extensive information regarding potential materials and the standards that they fall into as well as some strength properties. Can be used to find alternatives to materials selected should the need arise in testing
21CFR110	TITLE 21--FOOD AND DRUGS CHAPTER I--FOOD AND DRUG ADMINISTRATION DEPARTMENT OF HEALTH AND HUMAN SERVICES SUBCHAPTER B--FOOD FOR HUMAN CONSUMPTION PART 110 CURRENT GOOD MANUFACTURING PRACTICE IN MANUFACTURING, PACKING, OR HOLDING HUMAN FOOD	Provides guidelines for human contact with food and food surfaces as well as maintenance in order to maintain general cleanliness/sanitary operation of surfaces. This aids greatly for the future operations manual portion of the project.

FDA Food Code: 4-101	Chapter 4 - Equipment, Utensils, and Linens Part 4-1 - Materials for Construction and Repair Subpart 4-101 - Multiuse	Describes the characteristics a design must adhere to in addition to guidelines of specific materials' use limitations to maintain safe use.

The standards found range from material specific standards, to fastener standards, to assembly (welding) standards, and food safety standards. The material specific standards provide information regarding the materials that we have selected thus far. This also provides basic information including strength requirements of the materials, so the team has reasonable estimates when performing calculations. The fastener standards provide guidelines as to the sizing of the specific fasteners in order to adhere to the guidelines provided. This allows us to maintain reasonable tolerances on the holes in the parts without having to worry about clearances. Welding standards help to provide guidelines to the safety of welding as well as information that will be helpful when determining the ideal welding procedure. Food safety standards will be useful in the upcoming operations manual to ensure that the team considers proper usage and maintenance of the device to avoid harming anyone that uses the device. All of these are summarized by standard in Table 4 above.

3 Testing Procedures (TPs)

Testing the roller and dispensing systems are critical in the team meeting the customer and engineering requirements. Requirements such smooth edges, time to produce one roll, center of gravity, and material strength will be tested using traditional hands on methods to verify that they meet the engineering requirements. Requirements such as weight, volume, cost, and footprint will be evaluated using computer programs. The values will be gathered and then compared to the goal values to see if they meet the requirements. Using computer programs along with hands one test allows the team to have a better scope of how the engineering requirements are being met.

3.1 Testing Procedure 1: Smooth Edge Test

This test will verify that all edges of the device are smooth and will not cause any harm to the user. The engineering requirement being tested is smooth edges. The goal value the team has in place to achieve this requirement is to have all edges filleted with a radius of 5mm or less. The first portion of this test will be reviewing the SolidWorks files and making sure all fillets are 5mm or less. Then using an inflated balloon, a team member will move the balloon across all the prototypes surfaces to see if it pops. This test will be completed after the final prototype is built.

3.1.1 Testing Procedure 1: Objective

After reviewing the SolidWorks part files, a balloon will be inflated to the point just before popping to allow for extra sensitivity. The inflated balloon will then be dragged across all surfaces and edges testing for smoothness. If the balloon pops the test is failed. If a part fails the test it will be taken to the machine shop where all edges will be ground and radiused again. After regrinding the test will be performed until all surfaces pass. This test is testing the smoothness of the edges and how safe the device is to use. This test simulates a user coming in contact will the surfaces of the design with the balloon popping being correlated with harm to the user.

3.1.2 Testing Procedure 1: Resources Required

Table 5: Resources for Test 1

Resources	**Description**
People	Team members
Balloon	Party balloon style not water balloons
Device	Device disassembled so all surfaces are testable
Location	Any available space

3.1.3 Testing Procedure 1: Schedule

This test can take from a couple minutes to an hour if the device fails and need to be taken to the machine shop. The team will run this test once all the parts are manufactured. Since the test will be done after all the part are completed this test will take place early in second semester. Manufacturing the parts is the only prerequisite to testing this requirement.

3.2 Testing Procedure 2: Roll Production Time

In the Roll Production test, the engineering requirement of rolling one roll in 30 seconds or less will be evaluated. Using the final prototype, the team will use volunteers that have little instruction to see how long it takes them to produce one roll. The uneducated volunteers will represent children first learning how to use the device. This test will take place after the final assembly and drop test of the team's device.

3.2.1 Testing Procedure 2: Objective

After final assembly has been completed at set of ten volunteers will be gathered. The volunteers will be given brief instruction on how to use the device. Cocoyam leaves will be prepared ahead of time with the cocoyam paste spread to the correct dimensions. Each volunteer will be handed the prepared leaf and asked to roll it using the device. The timer will be started once the volunteer is handed the leaf and stopped once the roll is completed and in the divot in the roller base. If the volunteer completes a roll in under 30 seconds the test is passed any time over 30 seconds the test is failed. If the test is failed the user will be given additional instruction. If the test is still failed the areas of inefficacy will be reviewed. This test uses time to test the ability of the user to quickly learn and operate the device.

3.2.2 Testing Procedure 2: Resources Required

Table 6: Resources for Test 2

Resources	**Description**
People	Volunteers varying in age
Timer	Stopwatch to measure time to roll
Cocoyam Paste	Grated cocoyam and spice mixture
Device	Device completely assembled
Location	Any available space

3.2.3 Testing Procedure 2: Schedule

Each test will take roughly one minute. If addition instruction is need it make take up to three minutes. This test will be conducted after the edge test and final assembly. The team plans to run this test after the drop test in the beginning of the second semester. Complete assembly of the device must be completed before the test can be conducted.

3.3 Testing Procedure 3: Drop Test

A drop test will be performed to evaluate the strength of the design and the design's material. This test will evaluate how the team met the engineering requirement of material strength. Testing will consist of pushing off or dropping the device from a surface approximately one meter high. The one-meter high distance is representative of a countertop of carrying height of a person. Running this test after complete assembly and the smooth edge test allows the team to test the device under more accurate conditions. Running the test before the edge test may subject the device to higher stress concentrations on any surface that is not radiused. If deformation does occur during the drop test the edge test will be performed again after the surfaces are refinished.

3.3.1 Testing Procedure 3: Objective

To start the test the device will be placed on a countertop approximately one meter from the ground. A team member will then push the device of the edge of the counter causing the device to impact the ground. After the device impacts the ground it will be checked for deformation. If the device has any broken parts or deformation that causes the device not to function the test is failed. If little or no deformation occurs the test is passed. This test will be performed on both the roller and dispenser since they are both subject to being dropped. After the devices passes that section of the test a team member will hold the device with their arms parallel to the ground and drop the devices. Using the criteria from above the devices with be given a pass or fail. If the devices does not pass either portion of the test a redesign of the part will be conducted in increase the parts strength. The drop test is testing the strength of the device along with its resistance to deformation. The test does this by subjecting the device to similar amount of force the device may see in use or if dropped.

3.3.2 Testing Procedure 3: Resources Required

Table 7: Resources for Test 3

Resources	Description
People	Team Members
Countertop	Approximately one meter high
Device	Device completely assembled
Location	Any available space

3.3.3 Testing Procedure 3: Schedule

This test will take approximately ten minutes to complete. If the device fails it will take longer since repairs may be needed along with retesting. The team will complete this test after the edge test to reduce stress concentration on the edges. The edge test and full assembly must be completed before this test can take place. The test is scheduled for the beginning of second semester.

3.4 Testing Procedure 4: Stability Test

The stability test will test the ability of the team's design to resist tipping over. Forces will be applied at predetermined locations on the device to see if the designs fall over or is stable. The engineering requirement being tested is a low center of gravity. If the device has a low center of gravity it will not tip over with average size forces being applied. This test will be run first using SolidWorks to find the actual center of gravity and then in person after the drop test.

3.4.1 Testing Procedure 4: Objective

The first portion of this test will be to use SolidWorks to find the actual center of gravity of the device. The center of gravity will be different for the dispenser and roller so it will be computed for both. Once the centers are located a force will be applied to the top, bottom and middle of each device as separate portions of the test. If the device tips over on any portion of this test the test is failed. If it stays up right the device passes the test. If failed the device will be redesigned in SolidWorks to lower the center of gravity. The amount of forced being applied will be measured by a pull gauge. The force will increase in increments of five pounds until 20 pounds is reached. Using this test quickly evaluates if the center of gravity is in the correct position to prevent any malfunctions while in use.

3.4.2 Testing Procedure 4: Resources Required

Table 8: Resources for Test 4

Resources	**Description**
People	Team members
Pull Gauge	Gauge that can measure up to 20lbs
Device	Device completely assembled
Location	Any available space

3.4.3 Testing Procedure 4: Schedule

This test will take approximately ten minutes per device. Since the force will be applied multiple times in multiple locations it will take longer than the previous test. This test will be completed after all the other test since they may cause major design changes. The team has placed this test at the end of the beginning of second semester to accommodate for the other test and redesigns.

3.5 Testing Procedure 5: Analysis Software Test

For the engineering requirements that can be validated with numerical values that either meet or fail to meet our goal values, software will be used. The engineering requirements being tested using software are factor of safety of the fasteners, mass, footprint, volume, and cost. Using the properties tab in SolidWorks along with excel files specific to factor of safety and costing the requirements will be tested. The test will be evaluated on a pass or fail system.

3.5.1 Testing Procedure 5: Objective

The first portion of this test will be run using the properties tab in the SolidWorks files. Each of the engineering requirements has an acceptable value such as a mass less than seven kilograms, footprint under $0.125m^2$, and volume under $0.02m^3$. The test will consist of comparing the goal values to the values in the properties tab. If the value is less than the desired the system passes if it is higher the system fails. If a part fails it will be redesigned to meet the desired value. For the excel portion of the test, a spreadsheet created to measure the factor of safety of fasteners along with the bill of materials will be used. The requirements being tested for this portion are a factory of safety of five for the fasteners, and a total cost under 45 dollars. The desired fastener's specification will be inputted in to excel spreadsheet where factor of safety is calculated. Using the bill of material and values from the properties tab in Solidworks a total amount of material needed will be calculated multiplied by the cost of the material. For either to pass this portion of the test the must meet or exceed the factor of safety and be under the desired 45 dollar amount. If they fail the test they will be redesigned and tested again.

3.5.2 Testing Procedure 5: Resources Required

Table 9: Resources for Test 5

Resources	**Description**
People	Team members
Software	SolidWorks
Software	Excel for factor of safety of fasteners, BOM

Device	SolidWorks Model
Location	Any available space

3.5.3 Testing Procedure 5: Schedule

This test will take approximately ten minutes with the largest amount of time being spent on the cost analysis. This test will not be run second semester but has already been completed during the first semester. This test was done first since it is critical in meeting many of the engineering requirements along with having the most effect on the overall design.

4 Risk Analysis and Mitigation

This section focusses on the risks based on the FMEA which can be found in Appendix B. These failures are ranked based on the RPN, which is generated from multiplying severity, occurrence, and detection. The subsystem is broken down into four subsystems. The four subsystems are the Roller base, Roller, Dispenser and revisor. Each part sub system is broken down to function of each part within the subsystem. Each Function has a potential failure mode and effects. Based on the potential failures and the effects the severity, occurrence, and detection are determined. The severity number represent the Severity of the potential failure on the system. The detection number represent the ease in which the failure can be occurred. The occurrence number represent the likelihood of the failure to occur. The numbering scale is from one to ten with the highest number being top. The failure mode RPN is determined by multiplying the severity, occurrence, and detection. After determining the RPN number for each failure a recommended action is suggested to prevent the potential failure from occurring. In the next section the failures are represented based on the RPN from the highest to the lowest.

4.1 Critical Failures

4.1.1 Potential Critical Failure 1: Blockage of nozzle RPN= 128

The highest potential critical failure was the blockage of the nozzle through the dispenser Subsystem. This subsystem has the highest RPN of 128. This potential failure was caused because of the clogging through the nozzle of the dispenser, in which it can cause the whole system to stop dispensing the cocoyam product. Visual inspection could be conducted to indicate the potential failure. To overcome the blockage of the dispenser's nozzle the user should monitor the consistency of the cocoyam while dispensing.

4.1.2 Potential Critical Failure 2: breakage of side rails RPN =72

The breakage of the side rails throughout the roller base subsystem has second highest RPN number of 72. This potential failure is caused due to an excessive amount of downward forces on the side rails, which could cause a misalignment of the rolling process of the cocoyam across the rails of the roller base. This potential failure could be indicated by a visual inspection on the sides of the device. By replacing the side rails on the roller base as an immediate action would solve the failure.

4.1.3 Potential Critical Failure 3: Belt rips RPN = 60

The belt rips of the roller subsystem are one of our main potential failures. This is a critical failure because it causes the belt to be torn or worn. This potential failure is caused due to an excessive downward force on the belt. This potential failure will cause the whole process to be paused due to the inability of rolling the cocoyam due to a ripped belt. This potential failure could be indicated through a visible inspection of the belt frequently. As a recommended action a change of the belt is required as soon as possible.

4.1.4 Potential Critical Failure 4: Reservoir - Deformation of walls RPN = 54

One of the reservoir potential failure is the deformation of the walls, which has the fourth highest RPN value of 54. This potential failure is caused by an excessive angular force being applied to the sides of the walls. This failure will disable the usage of the plunger in the reservoir to dispense the cocoyam through the nozzle. A simple visual inspection is conducted to detect the deformation of the walls. Avoiding excessive forces on the walls of the reservoir will help in decreasing the cause.

4.1.5 Potential Critical Failure 5: Roller base - Base deformed RPN = 48

Deformation of the Roller base is the fifth potential failure with an RPN value of 48. The base of the roller is deformed due to an excessive downward force from the user. This failure will cause a deflection in the base of the roller. This failure is simply detected by a visual inspection from the user. Avoiding an excessive amount of force will simply overcome the deflection.

4.1.6 Potential Critical Failure 6: Dispenser – Plunger base plate bending RPN = 48

The plunger base plate bending is one of the potential failures of the design. This failure has an RPN of 48. The deformation failure can be caused by an excessive downward force on the base of the plunger. This cause results in either a deflection on the base of the plunger or a plastic deformation of the base of the plunger. While conducting a visual daily inspection on the plunger before usage will detect the problem. Avoiding an excessive force on the plunger will reduce the deflection rate.

4.1.7 Potential Critical Failure 7: Roller - Bracket not assembled/loosened RPN = 40

The Roller brackets is one of the potential failures with an RPN value of 40. This failure mode will cause the handle to be detached from the roller due to the fasteners dislodging. This potential failure is easily detected by a visual inspection of the device. Tightening the handle and fastening the brackets will help in preventing the handle to be detached.

4.1.8 Potential Critical Failure 8: Reservoir - Walls coming apart RPN = 40

The walls coming apart in the reservoir is another potential failure caused by the welding breakage. This potential failure has an RPN of 40. The walls coming a part is caused by an excessive outward force. The walls coming apart can be detected by visual inspection of the wall. Avoiding excessive forces can eliminate the failure of the walls coming a part.

4.1.9 Potential Critical Failure 9: Roller base - Fasteners Loosen RPN = 36

Fastener in the roller base are a main component part in our design. This potential failure has an RPN of 36. The failure is caused by a simultaneous vibration as well as not properly assembled. This potential failure will cause and excessive wear of the fasteners additionally a huge misalignment o the roller base. A frequent visual inspection of the fasteners will detect the weariness of the fasteners. Fasten the brackets properly to overcome the issue.

4.1.10 Potential Critical Failure 10: Dispenser - Leakage of cocoyam RPN = 36

The leakage of cocoyam in the dispenser is the lowest potential failure with 36 RPN. The seal breakage will cause the cocoyam leakage. The failure will result in wasted cocoyam which is not sever in comparison to other failures. The seal breakage can be visually inspected. In case this failure occurs replacing the nozzle is recommended.

4.2 Risks and Trade-offs Analysis

The largest risk trade-offs the team analyzed involved material selection. Most of the critical failures the team's design would be subjected to involve deformation. The initial design material chosen by the team was a plastic. Plastic would offer a lightweight building material while being relatively cheap. But with these positives come the ability to easily deform the material and increased complexity when building the design in Africa. So, the team opted to take a risk and make the design out of stainless steel. Stainless is very rigid and allows for less deformation when using thinner sheets of material. With the current assembly facilities in Africa consisting mainly of metal working shops, choosing steel increase the ability for the design to be more easily recreated. The trade-off with this decision is the increased cost of the design along with an increase in the design's weight.

The top possible failures for the reservoir consisted of bending the plunger base plate, deformation of the walls, the walls separating, along with blocking the nozzle. All of these failures are interconnected with the amount of force being applied by the plunger onto the rest of the system. The team took the risk of adding a plunger to the system instead of relying just on gravitational forces to dispense the cocoyam. Adding a plunger increase the forces the system will experience while also adding complexity to the design. With increased forced the wall of the reservoir will be more likely to deform or separate if the forces get large enough. This situation is very possible but not likely to happen. The benefits of the plunger outweigh the negatives by a large margin. Adding a plunger allows the user to more accurately start and stop dispensing along with dispensing all the contents of the reservoir. It also allows the user to apply enough force to keep the flow moving preventing blockages which is the highest ranked failure for the reservoir. If the system does experience a blockage the user can use the plunger to increase the pressure in the reservoir to remove the blockage. For these reasons the teams final design will feature a plunger even with the associated risk.

Many of the other failures revolve around improper assembly or the use of substitute materials. When creating this design, the team was diligent in finding materials that were readily available in Central Africa as well as the United States. Once these materials and fasteners were found they then could be used in the design. Even with this research the team runs the risk of the manufacture substituting in different materials and fasteners that may look similar but do not share the same material properties. The use of improper fasteners can cause critical failures such as the assembly coming apart, wear due to lose tolerances, or damage to other components. The team's decision to implement fasteners instead of having all joints welded together puts the design at a higher risk of critical failure. But with the use of fasteners the design is more modular and more easily disassembled for cleaning and maintenance. The use of proper fasteners will not affect the devices functionality unless they are nor properly tightened. The use of the wrong material can cause the device to corrode or fail prematurely. By properly educating the users on how to assemble and maintain the device the team will likely prevent any of these failures making the risk worth it.

5 DESIGN SELECTED – First Semester

This chapter discusses the design selected for the first semester. This is illustrated through changes in the design since the Preliminary Report, mathematical calculations, prototype, and CAD modeling in order to select the final design.

5.1 *Design Description*

The following subsections contain various elements that contributed to the overall design as well as present the design selected by the team.

5.1.1 Calculations

Table 10:Fasteners and Fastener Factor of Safety [2].

Units			Metric	Yield factor of safety	np	22.1479864
Fastener			Screw	Load factor of safety	nL	22.1479864
Thread			M4 x 0.7	Joint separation FOS	n0	0
Grade			SAE 1	Fatigue factor of safety	nf	10.8081476
Top member thickness	t,top	mm	3.175			
Bottom member thickness	t,bottom	mm	3.175			
Top member modulus	E,top	MPa	585			
Bottom member modulus	E,bottom	MPa	585			
Minimum Length	L,min	mm	9.175			
Fastener Length	L	mm	14			

Table 9 utilizes equations in an Excel spreadsheet in order to determine the factor of safety for the fasteners (screws) specifically. This was used as a means to determine if the current material, screw type selection, material housing the fastener, and number of screws will suffice the factor of safety requirement. The fatigue factor of safety is approximately 10.8 which is well above the minimum engineering requirement of 3.

Table 11: Force required to push the handle.

Force required to push the handle		
Mass	0.39	Kg
Weight	3.79	N
gravity (x - direction)	1.70	m/s^2
gravity (y - direction)	9.66	m/s^2
Normal Force	2.36	N
Friction Force	1.18	N
Pushing Force	10.84	N

Equation 1 [3]

$$\sum F_x = F_p - F_f - g\cos(\theta) = 0$$

Equation 2 [3]

$$\sum F_y = N - W - g\sin(\theta) = 0$$

Equation 3 [3]

$$W = mg$$

Equation 4 [3]

$$N = w\sin(\theta) + g\sin(\theta)$$

Equation 5 [3]

$$F_f = \mu * N = 0$$

Equation 6 [3]

$$F_p = F_f + g\cos(\theta)$$

Equations 1 through 6 show the equations used to sum the forces required to find the pushing force for the handle. Based on the equations an excel sheet was created (Table 10) to find the pushing force which was determined to be 10.84 N. This low force ensures the ease of use to different types of users.

5.1.2 Changes From Preliminary Report

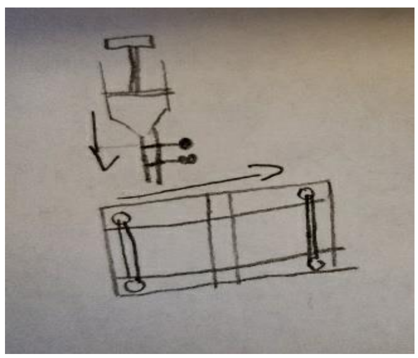

Figure 7: Full System Design - Preliminary Report

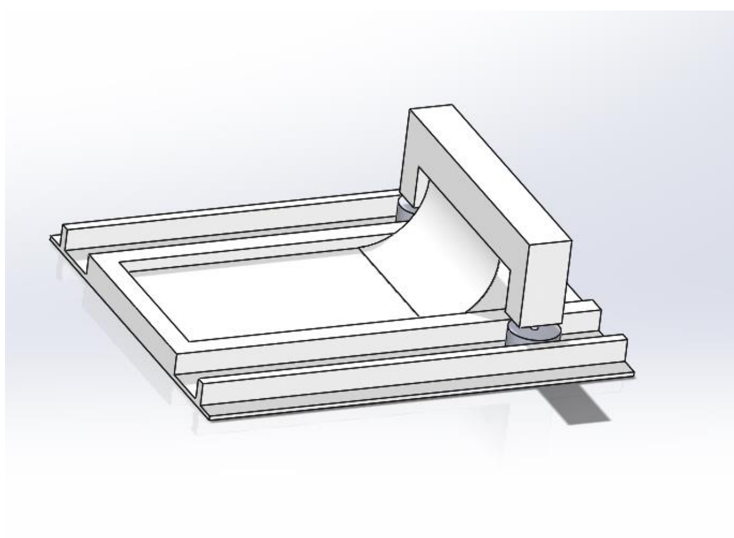

Figure 8: Roller Preliminary CAD

The original design selected by the team was that of Figure 7 from the Preliminary Design Report. In this concept, the cocoyam was dispensed from the dispenser directly onto the roller. From there, the roller was pushed in the direction of the arrow to roll the cocoyam into the final form. Since this design, the team decided to simplify the design by creating to independent systems and dispense the cocoyam away from the starting position of the roller. Additionally, the two-gate system of the original dispensing system shown in Figure 7 was removed due to a change in customer needs.

The roller design, shown more clearly in Figure 8, originally relied on a contoured end connected to a handle that was guided by two rollers on a guide rail. The team determined this design was ultimately unreliable and would be difficult to manufacture due to the inevitable specific contour required of the roller in order to produce the final product.

5.1.3 CAD Model and Explanation of Functionality

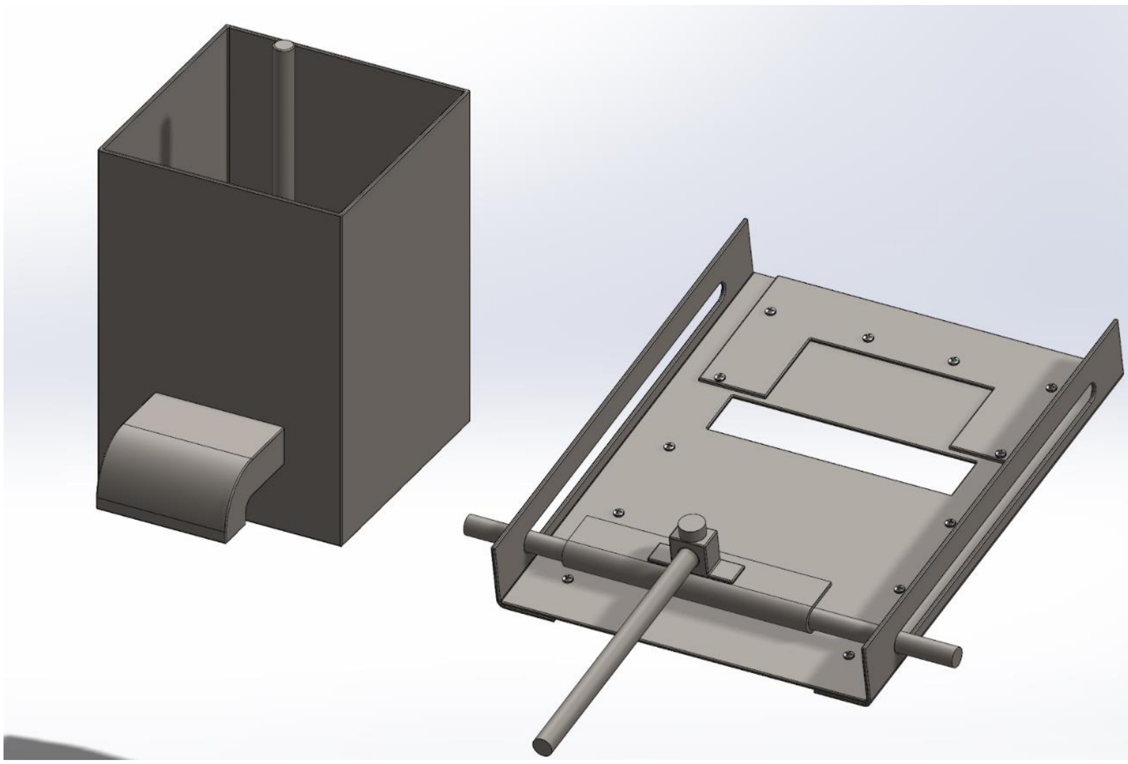

Figure 9: Full CAD Model of All Subsystems

Figure 9 above shows the current state of the CAD model at the top-level assembly of all subsystems. The left subassembly is the dispenser and its subsystems, and the right subassembly is the roller and its subsystem. Not shown (for clarity) is the flexible belt which is part of the roller assembly. This is assembled to the roller handle and extends the span of the base of the roller and is secured by the end bracket via pressure applied by the bracket when assembled with the fasteners. Views of the 3D CAD models as well as drawings are available in Appendix C.

The full system in Figure 9 features a two-stage dispensing and rolling process. The reservoir of the dispenser assembly is filled with cocoyam. This allows for mass preparation and temporary storage of the filling for Ekwang while the system is in use. The cocoyam is then forced through the nozzle on the front by the user pressing down on the plunger. The applied force forces cocoyam out the nozzle and into a leaf held by the user.

The second stage is the rolling process. The roller on the right in Figure 9 is composed of a base, 2 side rails, a roller bar, a handle, a two-part handle bracket, a pin for the handle attachment, an end bracket, and 12 screws and nuts for fastening, as well as a flexible belt which is not shown. The user places the leaf with the dispensed cocoyam onto the belt at the handle end. The user then grasps the handle and pushes forward along the guide rails to the opposite end of the device. At the cutout in the base, the belt is forced through the hole so that it creates a downward gap. As the roll is advanced toward the gap, the rolled dish eventually falls into the belt that is forced through the gap. The handle is pulled away back to the starting position. The result is the rolled cocoyam conveniently contained in the gap towards the base which allows for easy removal.

5.1.4 Prototype

Figure 10: Dispenser Subassembly Prototype

Figure 11: Roller Subassembly Prototype

Figure 10 and Figure 11 are images of the low fidelity prototypes created of the full system. They were constructed out of cardboard, a wooden dowel rod, tape, and staples. This prototype allowed the team to experiment with the current design and ensure functionality with the current state of the design. Prototyping assisted the team in identifying weaknesses in the design and how to improve upon the design in future iterations. Specifically, the team determined that some kind of railing was necessary in order to prevent the roller from traveling off the intended path. Walls can be seen in Figure 11 and later were incorporated into the model as guide rails. Additionally, the design for the handle as seen in Figure 11 was developed when the team discovered a need for an easier handle to grip than the original design that also prevented the belt from developing too large of a gap during the rolling process. The current handle design allows for a small amount of pressure to be applied to the backend of the belt to eliminate this unforeseen problem.

5.2 Implementation Plan

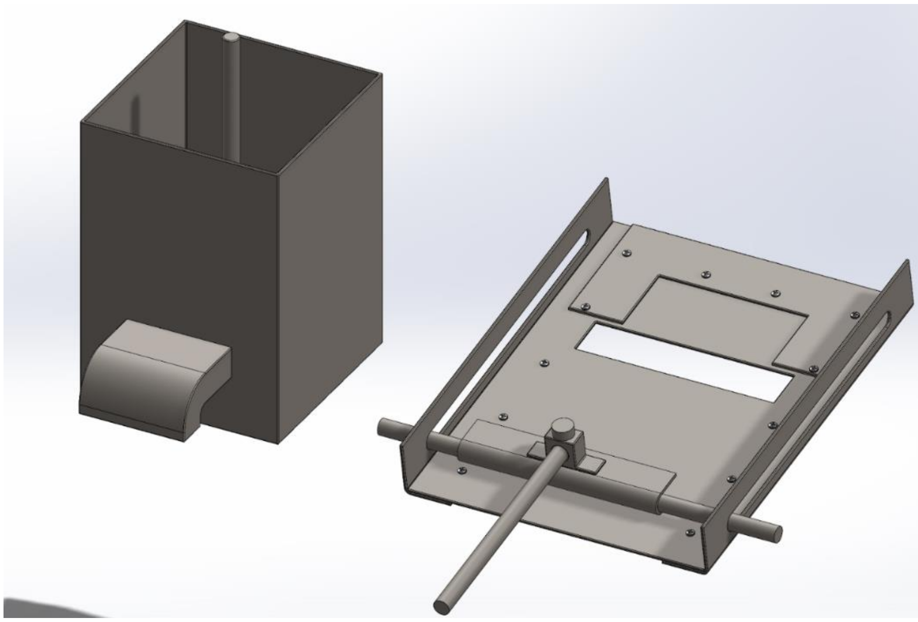

Figure 12: CAD Assembly View

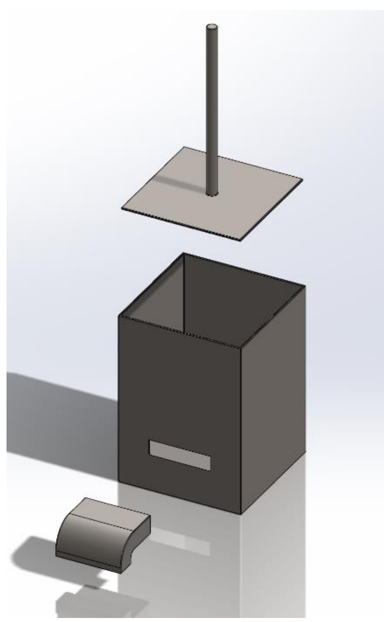

Figure 13: Dispenser Subassembly Exploded View

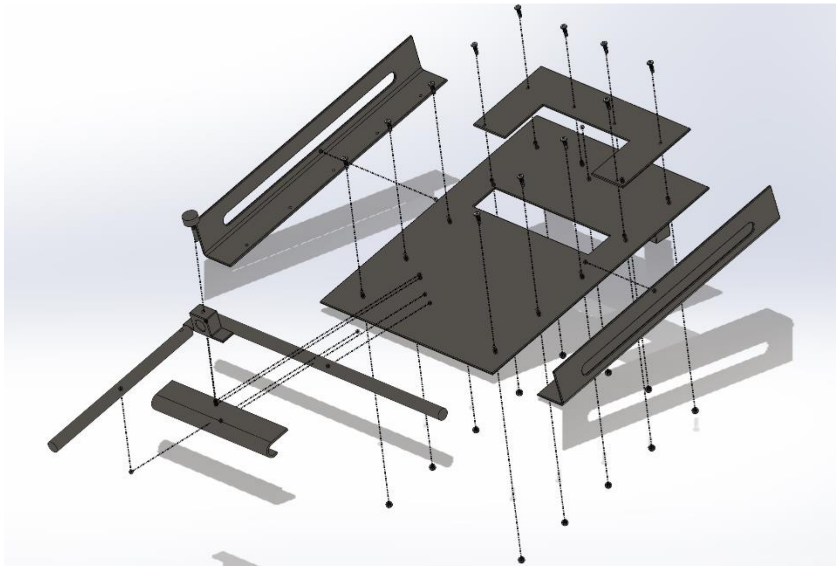

Figure 14: Roller Subassembly Exploded View

The implementation plan of the team is to fabricate a prototype composed of mainly 3D printed components to ensure that the current design will be efficient in performing the rolling and dispensing procedure. The low fidelity prototype in section 5.1.4 provided a proof-of-concept and first functioning prototype. The team learned from this prototype and made changes to the CAD accordingly. By producing additional prototypes and doing basic testing, it is expected that this will lead to better solutions for unanticipated obstacles. As testing occurs, the team plans to make continuous improvements to the design in order to provide the highest quality end product to the client.

To produce this high-fidelity prototype, the team will need access to the Cline Library 3D printing machines and the staff there which initiate the printing. A total printing cost as well as the cost of individual parts is available in the bill of materials located in Appendix D. Initial 3D printing will cost approximately $44.54. The materials purchased to produce the initial prototype cost $41.63, which leaves the total budget of $1458.37. The 3D prototype will leave a budget of approximately $1413.83 if the estimation is accurate. The team anticipates multiple iterations of prototyping and has allocated a prototype budge of approximately $500, which means there is $413.83 for modifications after the initial printing.

Printing of the current state of the design will begin the week of November 17th, 2019. As components are printed, they will be assembled into the final top-level assembly. Assuming printing may take a while, the team expects the process to print to take approximately one week. This will allow for preliminary testing of the more robust components as well as time for slight modifications before the Prototype Demo. Any additional modifications to the prototype and the design will occur 4-6 weeks after the Prototype Demo. Once the final design is decided based on the 3D prototypes, a prototype consisting of the final selected materials will be constructed. The team will need access to the machine shop, aid from the shop managers in the machine shop, and stock materials determined and purchased. This is anticipated to take approximately 2 weeks.

Modifications will occur as needed up until the Hardware Review the week of February 10th, 2019, at which point the design will be in its final state. The final product will then be constructed which is anticipated to take another 2 weeks, and should be completed prior to Spring Break, before the official deadline. This allows for unanticipated complications or obstacles that may extend these deadlines the team has set. When the final product has been constructed, testing is scheduled to take one to two weeks for thorough testing. When testing is complete, there are the final deliverables for the class, which are beyond the scope of implementation.

The final product to be delivered to the client is the drawings and model for the entire system so that it may be replicated in Africa. However, the final product the team plans to present will be the system constructed using materials similar to those available in Africa. The current bill of materials contains both the cost for 3D printing of the next iterative prototype as well as costs that would be comparable to the cost of manufacturing the components in Africa. The team was put in contact with an owner of a welding shop who provided very basic costing of metal. The team plans to do more research into specifics of manufacturing and materials in Africa beyond what has already been provided to ensure the final design can be implemented in Africa.

6 CONCLUSIONS

The team was presented with the challenge of creating a system that is as simple as possible for members of West and Central African communities to utilize and recreate. The client stressed the need for a simple design that was efficient. The team translated the conversations with the client to determine that the system needed to be low cost, contain as few parts as possible that were also simple to manufacture, and the overall design needed to improve upon the time it takes to prepare the dish, Ekwang.

The final solution proposed by the team is a two-stage system. Although the project only required a rolling device, the team decided to also create a dispensing system to attempt to improve upon the overall process. The dispenser features a three part assembly of a reservoir, a nozzle, and a plunger. Cocoyam is deposited into the reservoir where the plunger pushes it out of a nozzle when pushed in the reservoir. Cocoyam is forced through the nozzle onto a leaf where it will then be transferred to the rolling portion.

The rolling system itself is composed of a base, a rolling bar, assorted brackets, pins and fasteners to secure components in place, guide rails, and a belt. The dispensed cocoyam on the leaf is placed at the base of the roller. The user grabs the handle and pushes the handle along the guide rails towards the opposite end of the base. The leaf is rolled around the cocoyam to create the final dish, which is deposited into a gap in the base.

The team is confident that the current design is close to what the final design will be in the second semester. Through initial prototyping that has already been completed and future prototyping in the upcoming weeks, improvements will be made in order to deliver the best possible product to the client.

7 REFERENCES

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[2] Budynas, R. and Nisbett, J. (2008). *Shigley's mechanical engineering design*. Boston: McGraw-Hill Higher education.

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8 APPENDICES

8.1 Appendix A: House of Quality

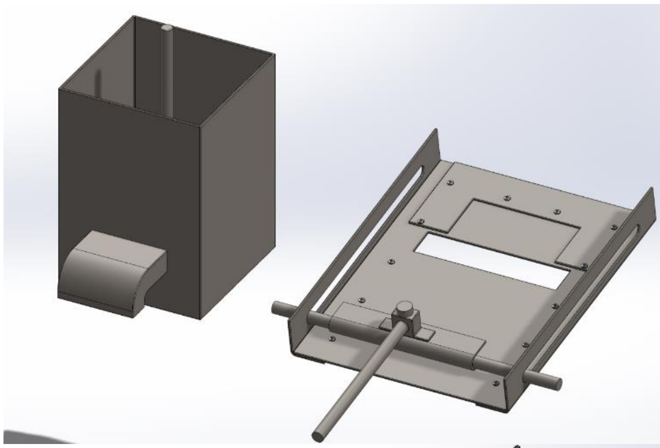
Customer Requirement/importance	Importance Ranking	Engineering Requirement	low weight	base footprint	volume of material to create device	smooth edges	low price	minimize time to produce one roll	material strength	material density	Low center of gravity	factor of saftey
1. realibilty	3		1	0	0	0	3	9	9	0	3	9
2. durability	2		3	0	0	3	3	1	9	3	1	9
3. lightweight	1		9	1	9	0	3	0	3	9	0	0
4. safe to use	3		0	0	0	9	0	0	3	3	1	9
5. simplicity	3		1	1	1	0	9	0	0	0	0	0
6. low cost	2		9	3	9	0	9	0	0	3	0	3
7. Easy to use by anoyne	2		1	0	0	0	3	1	0	0	3	0
8. mobility	1		9	9	9	1	0	0	0	3	1	0
9. faster than hand rolling	3		0	0	0	0	0	9	0	0	0	0
Absolute Technical Importance (ATI)			50	19	39	34	69	58	57	33	21	78
Relative Technical Importance (RTI)			11.8	4.1	8.5	7.4	15.1	12.7	12.4	7.2	4.6	17.0
Target ER values			7 kg	0.125 m^2	0.02 m^3	r=5 mm	$35.00	30 sec	44 MPa	1040 kg/m^3	-	3
Tolerances of Ers			>10 kg	>0.25 m^2	>0.1 m^3	<5mm	>$45.00	>60 sec	<44 MPa	<1040 kg/m^3	-	<3
Testing Procedure (TP#)			5	5	5	1	5	2	3	5	4	5

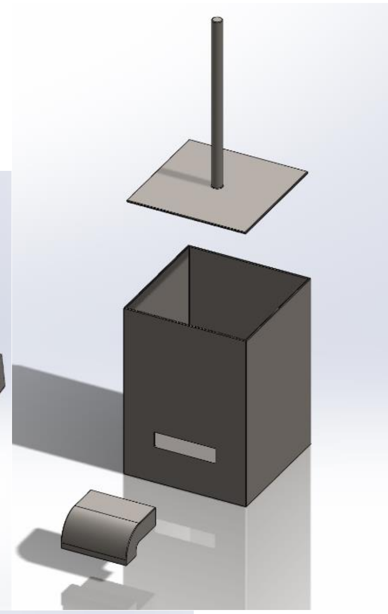
8.2 Appendix B: FMEA

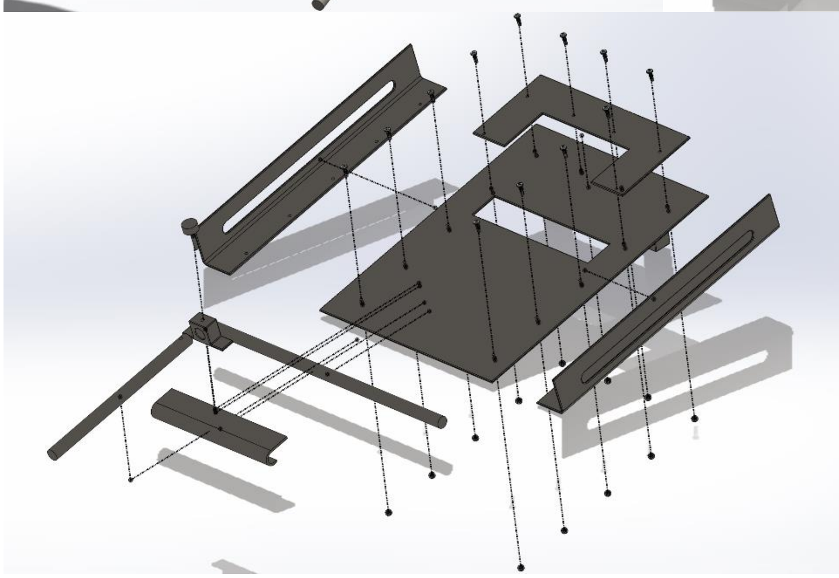
Product Name			Development Team : cocoyam	Page No of
System Name				FMEA Number
Subsystem Name				Date
Component Name				

Sub system	Part #	Function	Potential Failure Mode	Potential Effect(s) of Failure	Severity (S)	Potential Causes and Mechanisms of Failure	Occurance (O)	Current Design Controls Test	Detection (D)	RPN	Recommended Action
Roller Base	1	Roller Base	Base deformed	Deflection of base	6	Excessive downward forces	4	Visual Inspection/Indication	2	48	Avoid excessive force
			Base coming apart	Feet unstable/unfunctional device	10	Weld break/bracket disassembly	1	Visual Inspection/Indication	3	30	Replace brackets
			cracking of the base	Inability to roll	8	Corrsoion	1	Visual Inspection/Indication	1	8	keep the base dry
	2	Side Rails	Deform of side rail	Misalignment of rolling	5	Wear of device/improperly maufactured/improper assembly	1	Visual Inspection/Indication	2	10	Replace device
			breakage of side rails	Misalignment of rolling	8	Excessive downward forces on the ra	3	Visual Inspection/Indication	3	72	Replace Rails
	3	Fasteners	Fasteners Breakage	Disassembly	8	Excessive shear force	1	Visual Inspection/Indication	1	8	Replace brackets
			Fasteners Loosen	Excessive wear/misalignment	4	Vibration/improper assembly	3	Visual Inspection/Indication	3	36	Fasten brackets properly
	4	End Bracket	Detach from base	Belt is detached	5	Not fastened properly	2	Visual Inspection/Indication	3	30	Fasten brackets properly
			Bends	Belt has less clamping force/becomes loose	3	Tension (pulling) from belt	1	Visual Inspection/Indication	2	6	Replace brackets
	5	Crevice in base plate	Blockage	Inability to secure the roll from unfolding	2	cocoyam builds up in the crevice	2	Visual Inspection/Indication	2	8	clean up the crevice
Roller	1	Handle	Handle breaks	Potential harm to user	10	Moment on handle	1	Visual Inspection/Indication	1	10	Replace handle immediately
			Deforms	Potential harm to user	10	Excessive force from handle	2	Visual Inspection/Indication	1	20	Replace handle immediately
	2	Handle Bracket	Bracket not assembled/loosened	Handle detached	5	Fastener dislodged	4	Visual Inspection/Indication	2	40	tighten handle
			Handle instability	Handle detached	4	Bracket opening deformed	2	Visual Inspection/Indication	3	24	Replace brackets
	3	Roller Bar	Fracture of bar	Potential harm to user/unfunctional device	10	Excessive force from handle	1	Visual Inspection/Indication	1	10	Avoid excessive force
			Bar dislodged from rails	Inability to roll	7	Uneven applied force	1	Visual Inspection/Indication	4	28	Avoid excessive force
	4	Belt	Belt rips	Inability to roll	10	Wear of device/belt is torn	3	Visual Inspection/Indication	2	60	Replace belt
			Detach from bracket(s)	Belt is loose	6	Not fastened properly	2	Visual Inspection/Indication	1	12	Reattach belt
	5	Bolts	Bolt loosened	Handle loosened	4	Not fastened properly	3	Visual Inspection/Indication	2	24	Fasten Bolt
			Bolt Corrosion	breakage of bolt	2	Wear of bolt	2	Visual Inspection/Indication	1	4	Replace bolt
Dispenser	1	Nozzle	Blockage of nozzle	No dispensing of product	4	Clogging	4	Visual Inspection/Indication	8	128	Monitor consistency of product
			Leakage of cocoyam	Wasted product	2	Seal breaks	3	Visual Inspection/Indication	6	36	Replace Nozzle
			Breakage of nozzle	Unable to dispense	2	Corrsion	4	Visual Inspection/Indication	2	16	Replace Nozzle
			Fracture of nozzle	wasted product	1	Leakage of cocoyam	2	Visual Inspection/Indication	4	8	Replace Nozzle
	2	Plunger base	Base plate bending	Deflection/plastic deformation of base	6	Excessive downward force	4	Visual Inspection/Indication	2	48	Avoid excessive force
			Breakage of base	Inability to dispense	4	excessive upward forces	2	Visual Inspection/Indication	1	8	Replace base
			Fracture of base	Leakage of cocoyam	2	Excessive downward forces	3	Visual Inspection/Indication	1	6	Replace base
	3	Plunger Handle	Handle breaks	Potential harm to user	10	Moment on handle	1	Visual Inspection/Indication	1	10	Replace handle immediately
			Handle deformed	inabity to dispense	10	Excessive downward forces	2	Visual Inspection/Indication	1	20	Replace handle immediately
			Handle Fracture	Potential harm to user	10	Excessive downward forces	3	Visual Inspection/Indication	1	30	Replace handle immediately
Reservoir	1	Reservoir/Hopper	Walls coming apart	Weld break	10	Excessive outward forces	1	Visual Inspection/Indication	4	40	Avoid excessive force
			Fracture of walls	leakage of cocoyam	2	Excessive outward forces	1	Visual Inspection/Indication	4	8	Avoid excessive force
			Breakage of walls	inability to hold cocoyam	3	corrosion	3	Visual Inspection/Indication	3	27	Replace Reservoir
			Deformation of walls	inability to use plunger	6	Excessive Angular forces	3	Visual Inspection/Indication	3	54	Avoid excessive force
			Corrosion of walls	Inability to use device	7	aging of material	1	Visual Inspection/Indication	1	7	Replace Reservoir
			Over flow	wasted cocoyam	1	Excessive cocoyam pouring	1	Visual Inspection/Indication	1	1	Input cocoyam steadily
			Scratching of the walls	Hiding microorganisms	4	Useage of wrong cleaning supplies	2	Visual Inspection/Indication	3	24	Use proper cleaning supplies
			breakage of bottom surface	wouldn't stand	6	Excessive downward force	1	Visual Inspection/Indication	1	6	Avoid excessive force
			wear of the walls	Inability to use	10	Force from plunger	1	Visual Inspection/Indication	1	10	Avoid excessive force
			Scratch of bottom surface	Hiding microorganisms	4	Force from plunger	2	Visual Inspection/Indication	3	24	Avoid excessive force

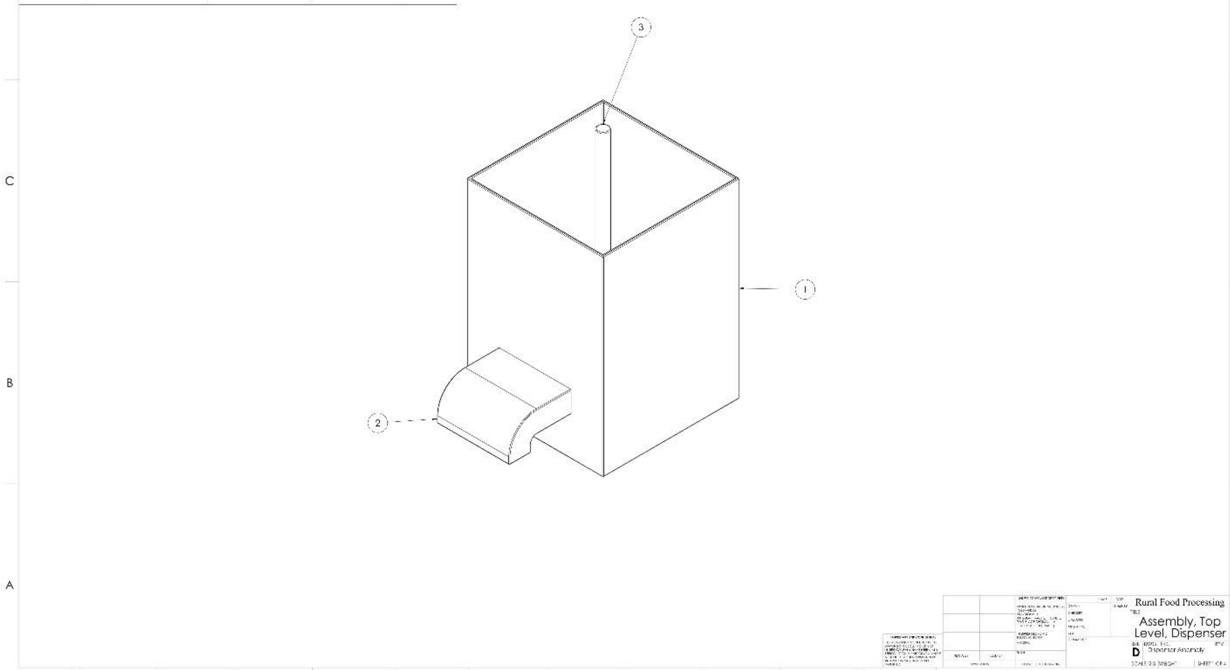
8.3 Appendix C: Current State CAD and Drawings

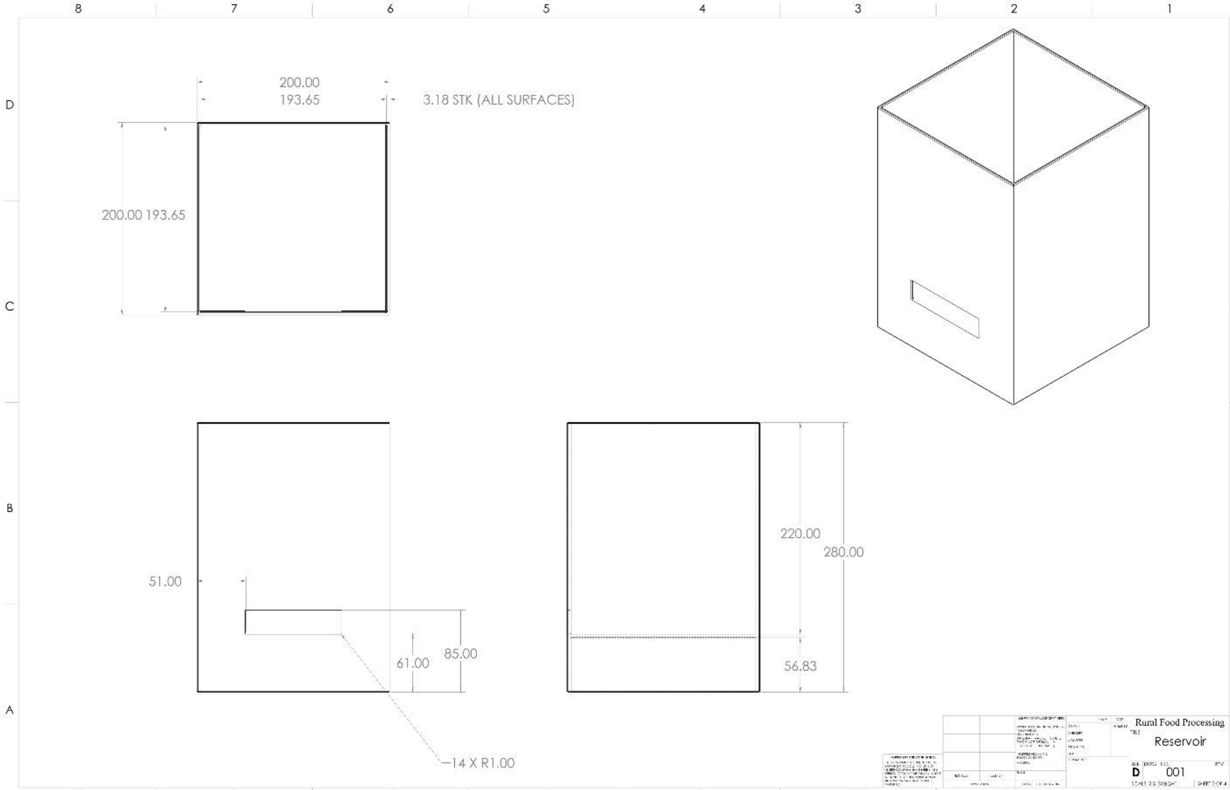


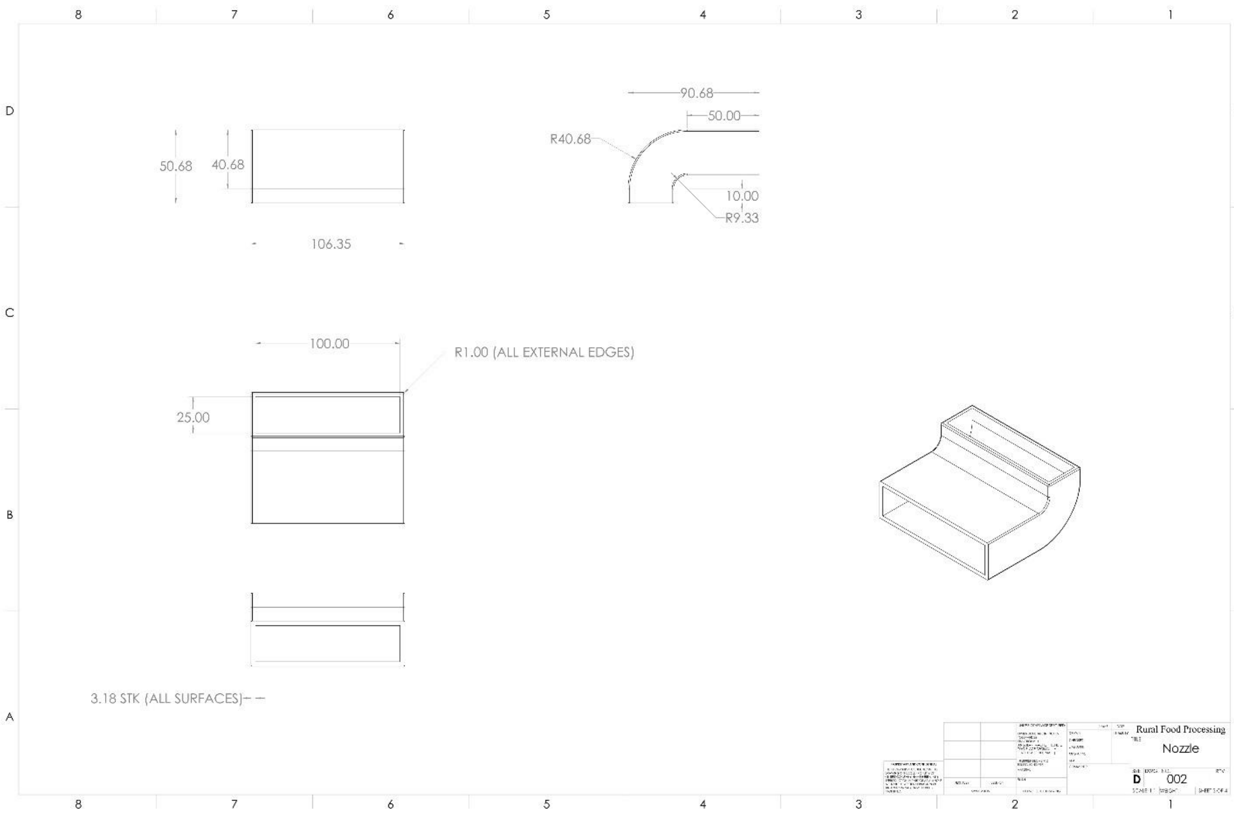


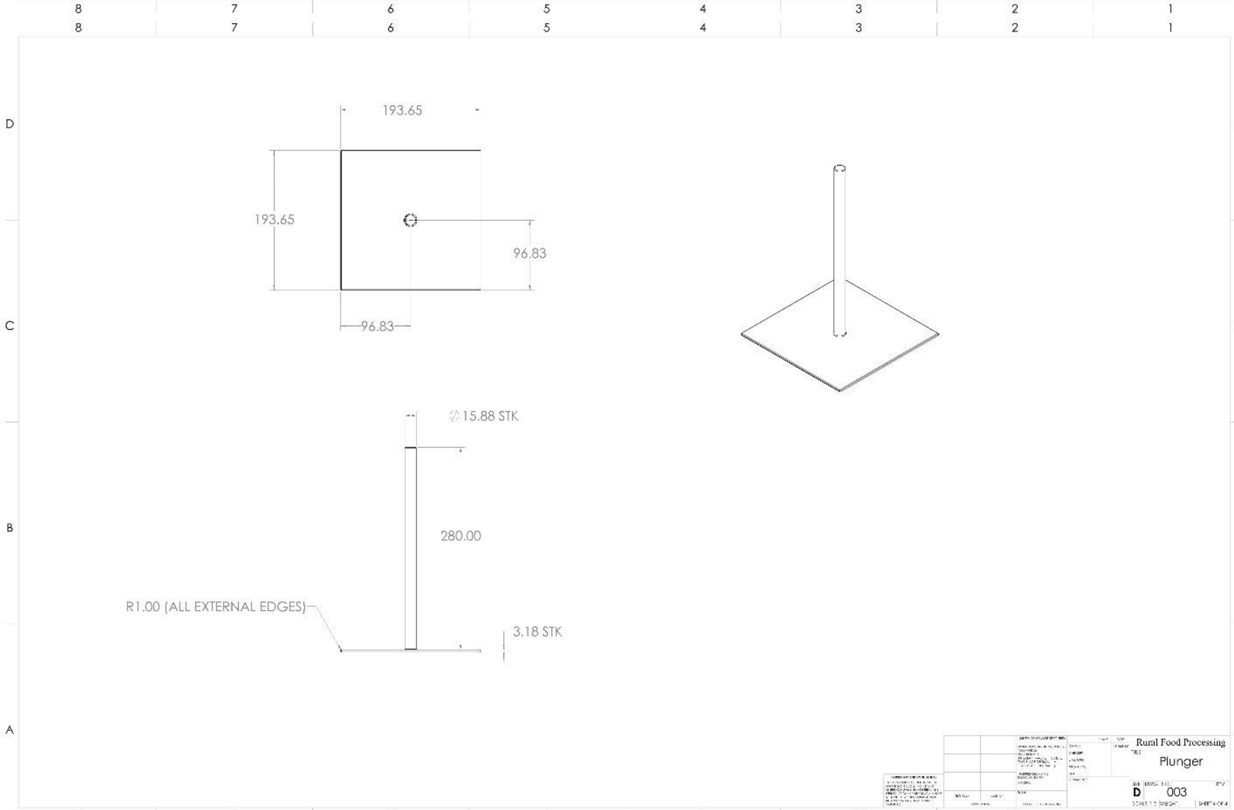


ITEM NO.	PartNo	DESCRIPTION	QTY.
1	001	Reservoir	1
2	002	Nozzle	1
3	003	Plunger	1

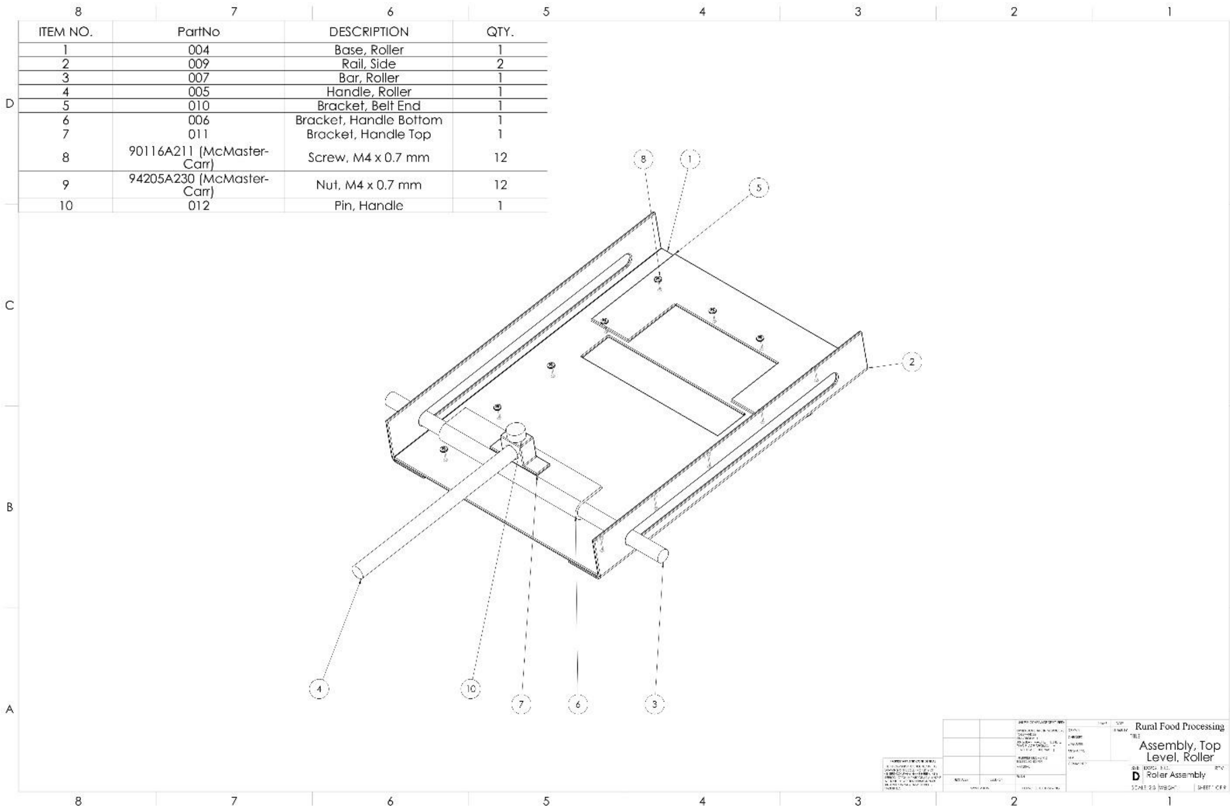


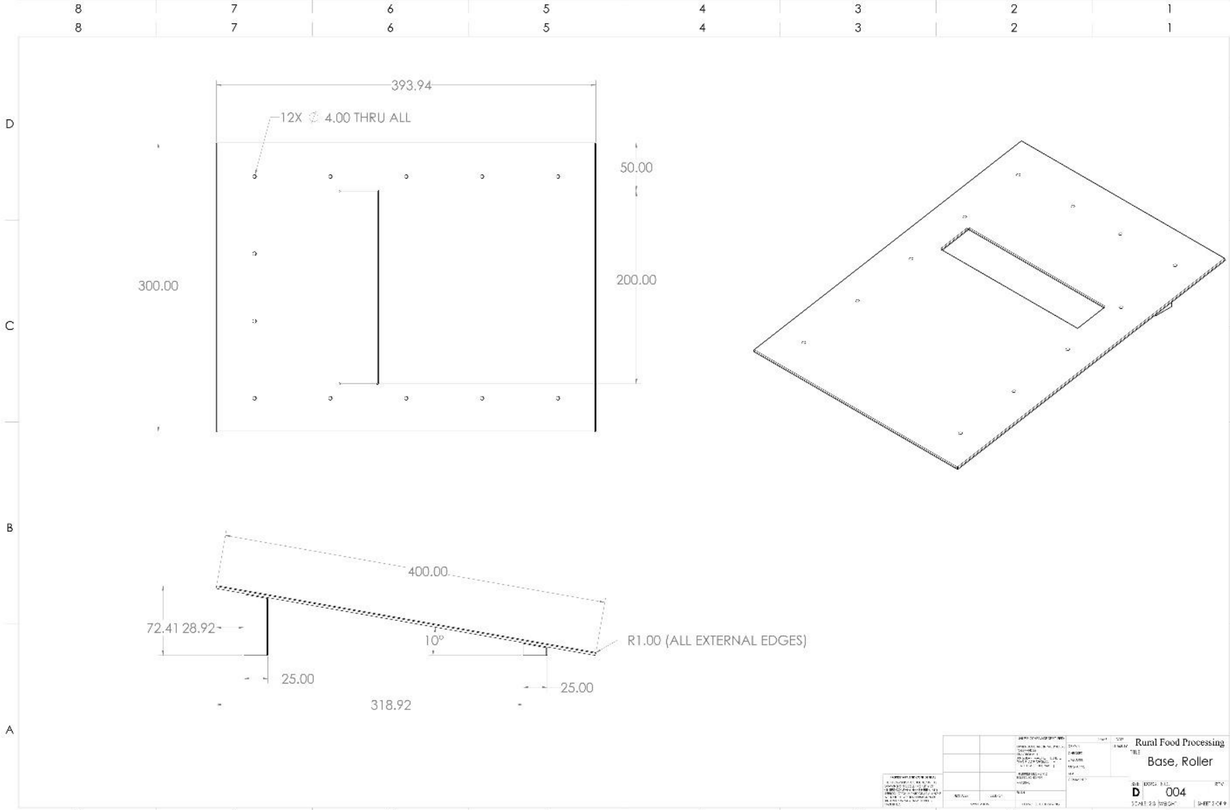


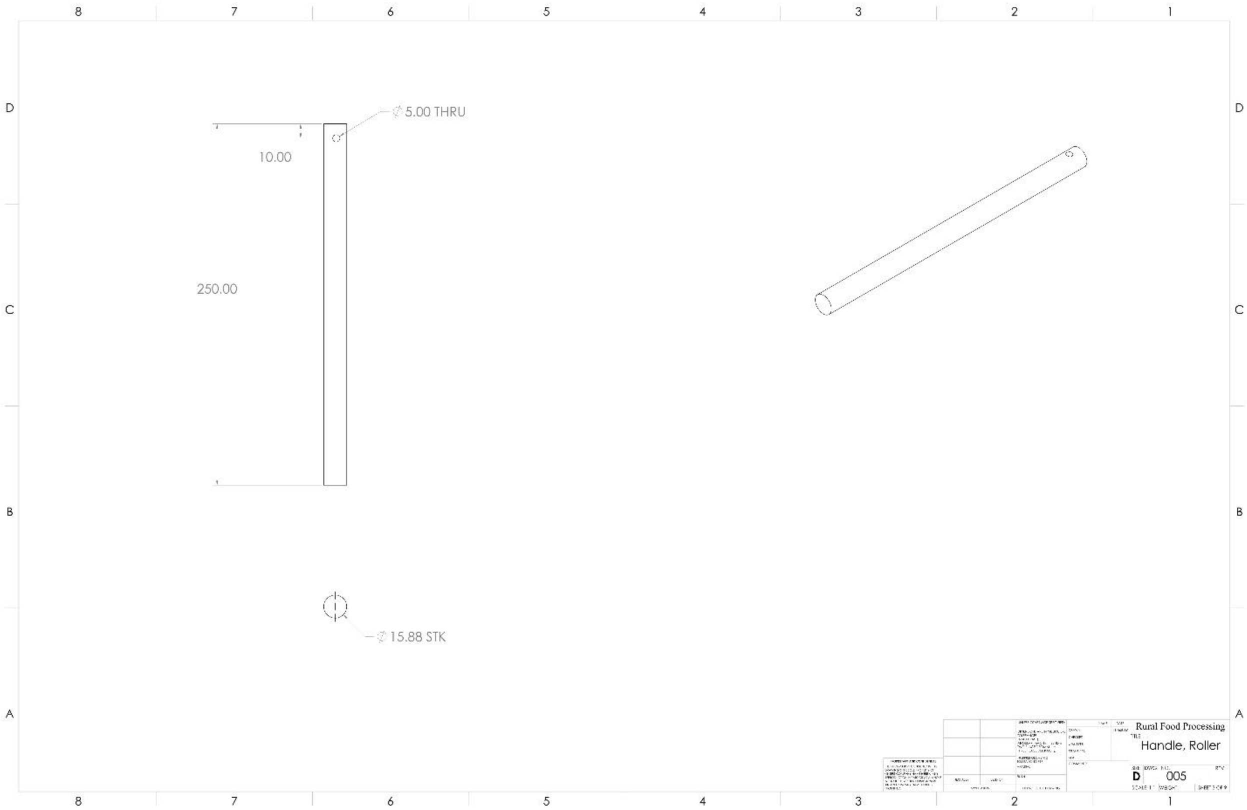

90.68
50.00
R40.68
50.68
40.68
10.00
R9.33
106.35
100.00
R1.00 (ALL EXTERNAL EDGES)
25.00
3.18 STK (ALL SURFACES)
Rural Food Processing
Nozzle
D
002


193.65
193.65
96.83
96.83
15.88 STK
280.00
R1.00 (ALL EXTERNAL EDGES)
3.18 STK
Rural Food Processing
Plunger
D
003

ITEM NO.	PartNo	DESCRIPTION	QTY.
1	004	Base, Roller	1
2	009	Rail, Side	2
3	007	Bar, Roller	1
4	005	Handle, Roller	1
5	010	Bracket, Belt End	1
6	006	Bracket, Handle Bottom	1
7	011	Bracket, Handle Top	1
8	90116A211 (McMaster-Carr)	Screw, M4 x 0.7 mm	12
9	94205A230 (McMaster-Carr)	Nut, M4 x 0.7 mm	12
10	012	Pin, Handle	1



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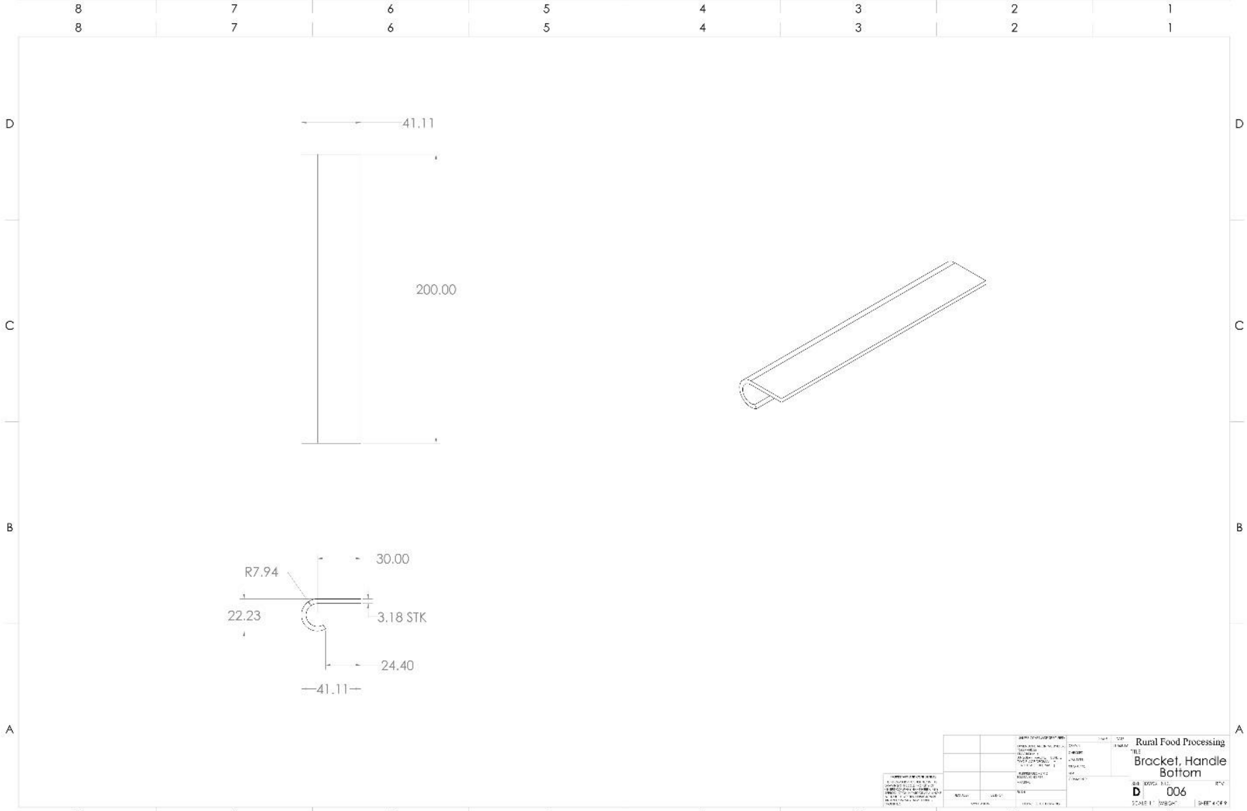
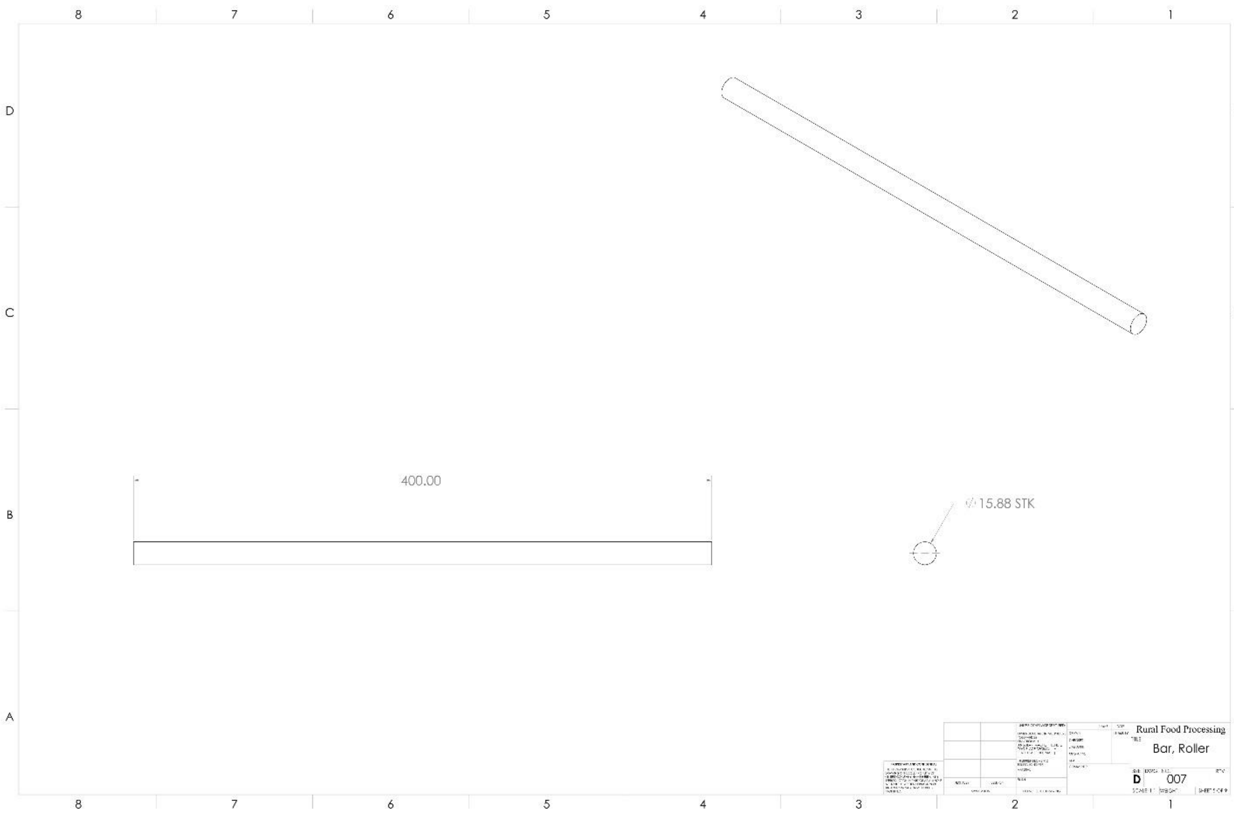
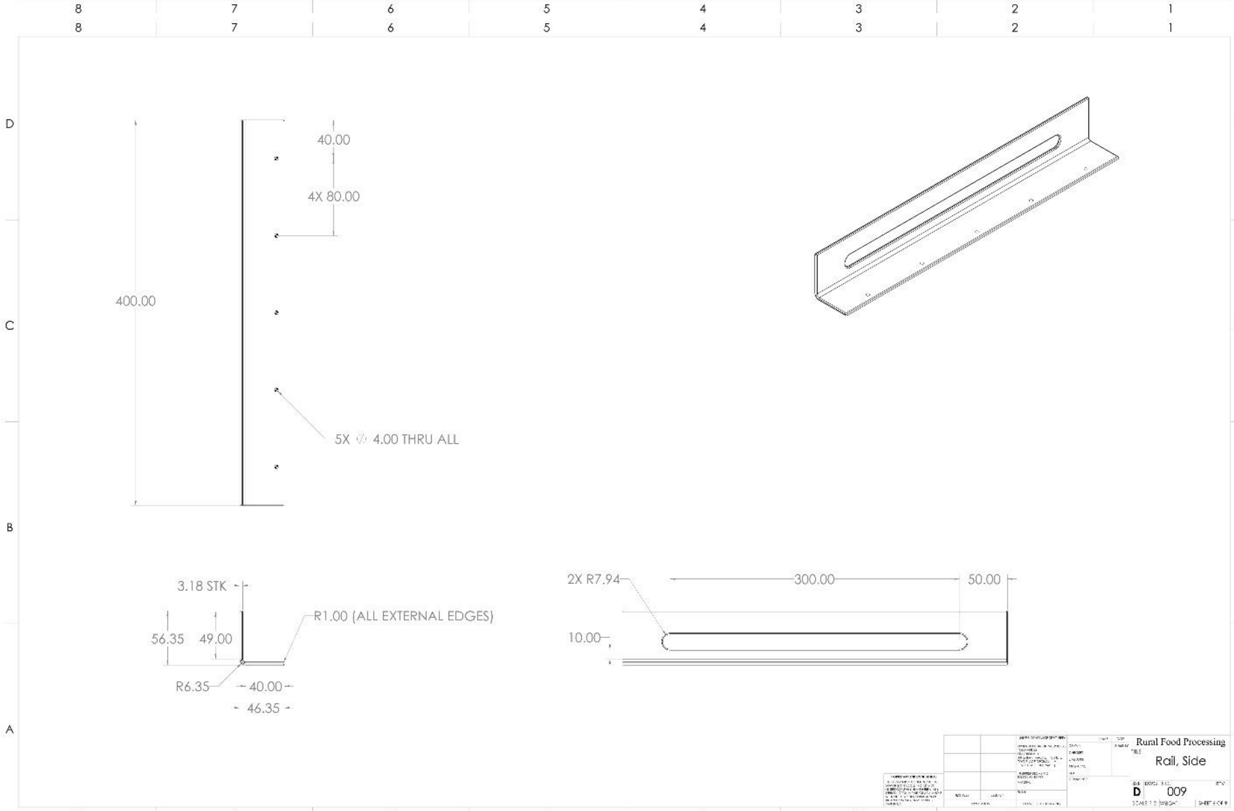
10.00
250.00
Ø 15.88 STK
Rural Food Processing
Handle, Roller
D
005


41.11
200.00
R7.94
30.00
22.23
3.18 STK
24.40
41.11
Rural Food Processing
Bracket, Handle
Bottom
D
006


400.00
⌀15.88 STK
Rural Food Processing
Bar, Roller
D
007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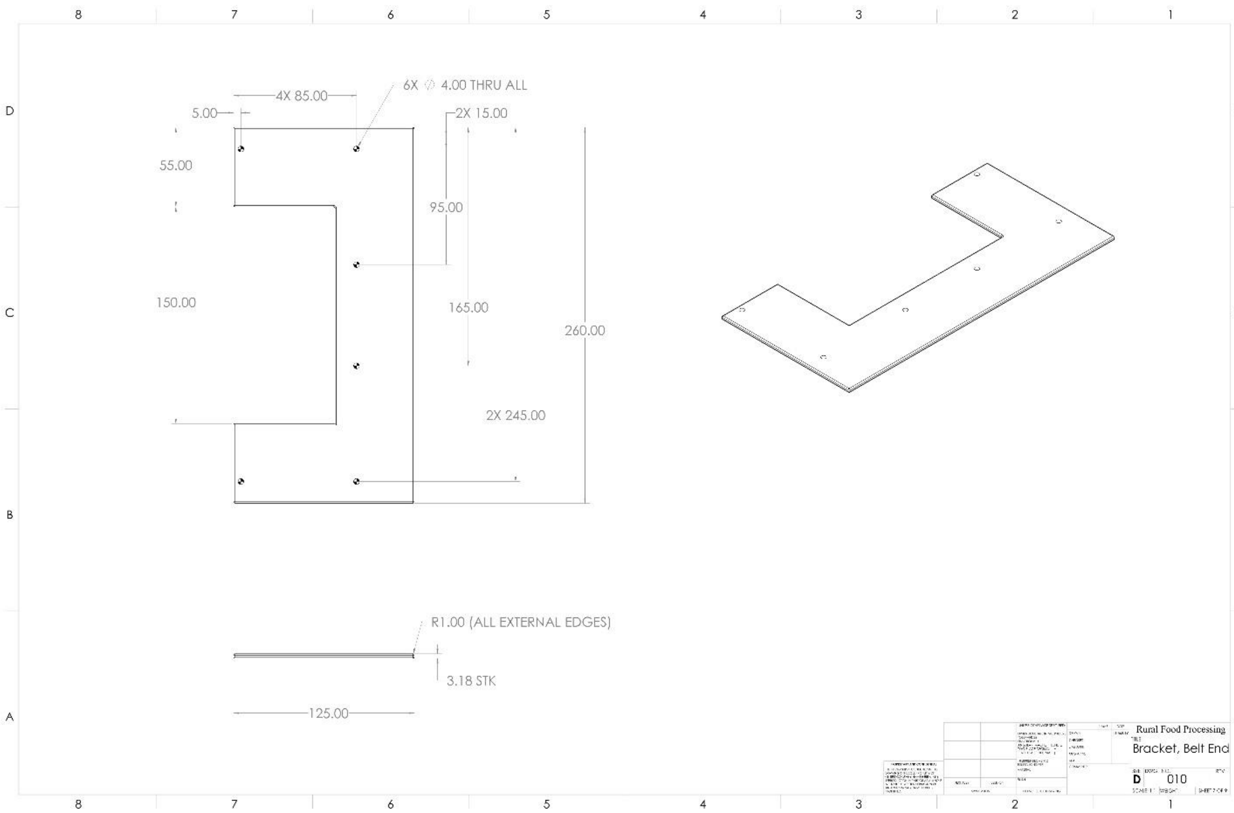
4X 80.00
400.00
5X ⌀ 4.00 THRU ALL
3.18 STK
R1.00 (ALL EXTERNAL EDGES)
56.35
49.00
R6.35
40.00
46.35
2X R7.94
300.00
50.00
10.00
Rural Food Processing
Rail, Side
D
009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4X 85.00
5.00
2X 15.00
55.00
95.00
150.00
165.00
260.00
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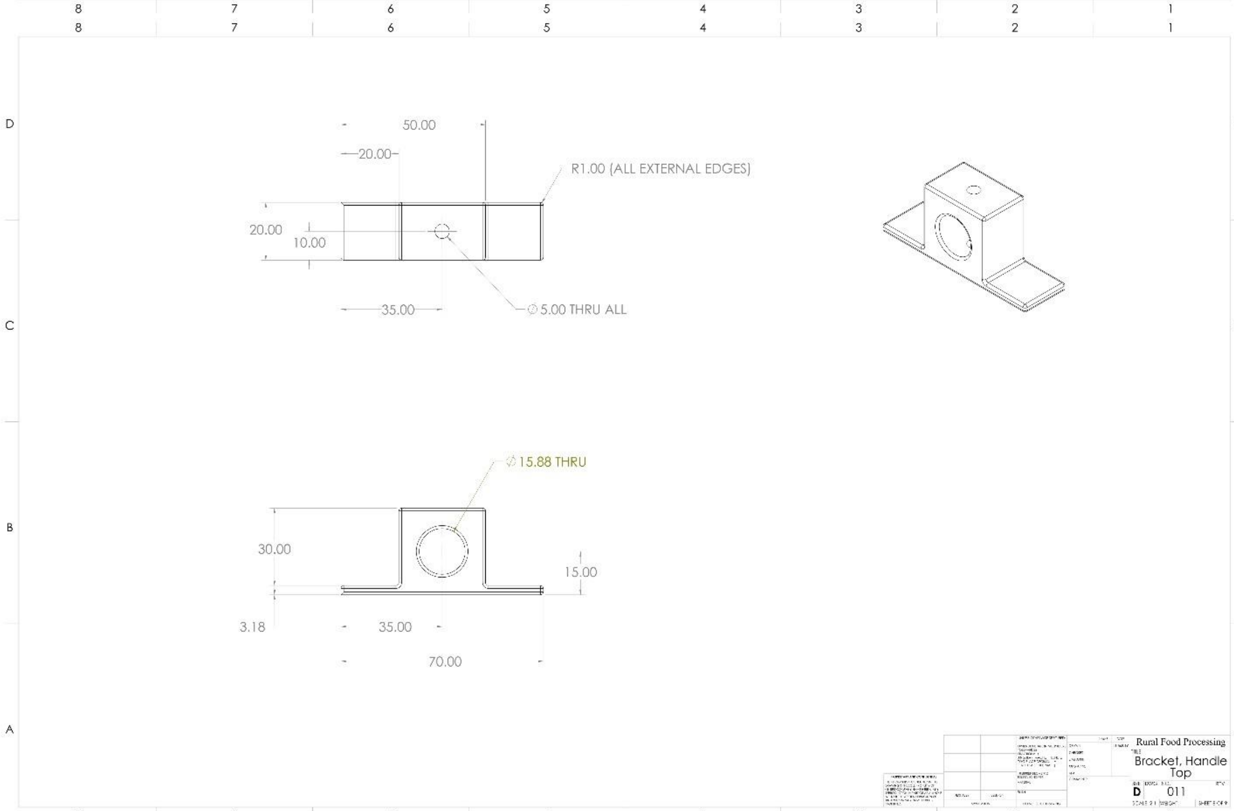
R1.00 (ALL EXTERNAL EDGES)
3.18 STK
125.00
Rural Food Processing
Bracket, Belt End
D
010


50.00
20.00
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20.00
10.00
35.00
∅ 5.00 THRU ALL
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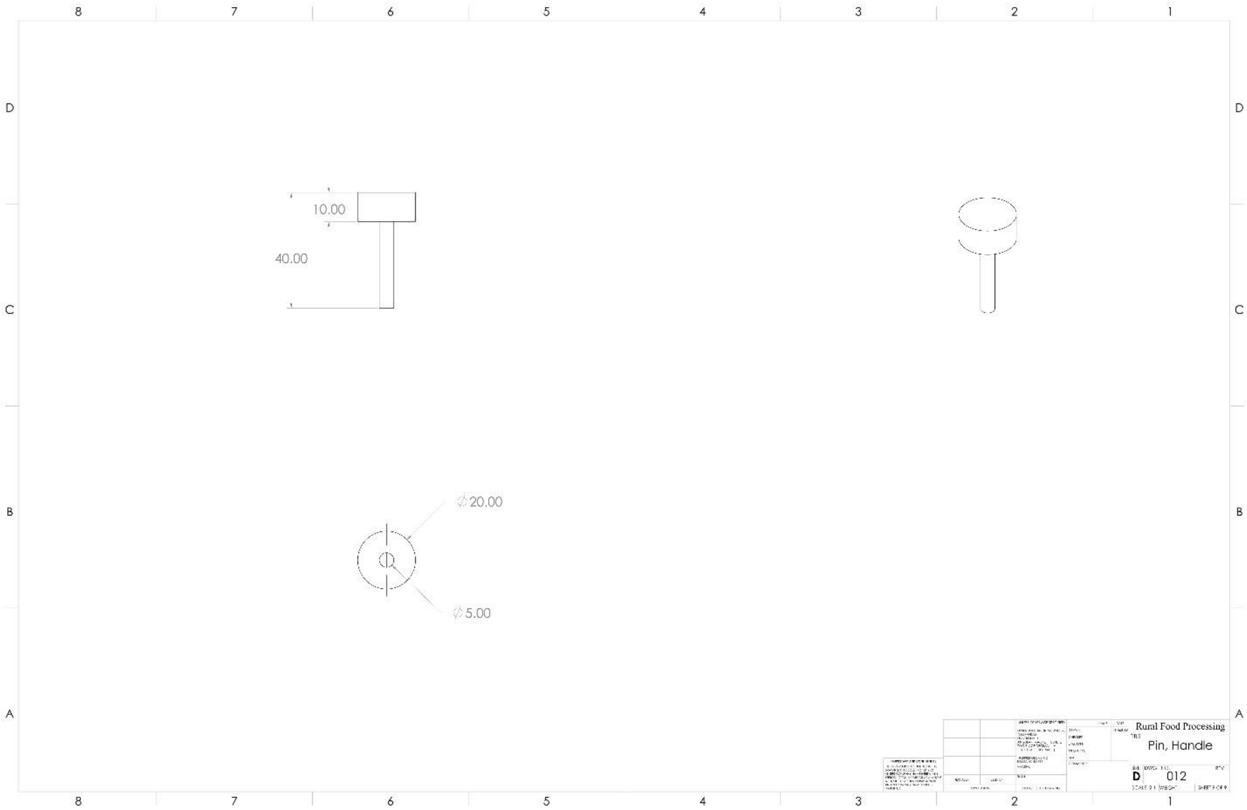
30.00
15.00
3.18
35.00
70.00
Rural Food Processing
Bracket, Handle Top
D
011


10.00
40.00
Ø20.00
Ø5.00
Rural Food Processing
TITLE
Pin, Handle
SIZE
D
DWG. NO.
012
REV

8.4 Appendix D: Bill of Materials

Bill of Materials - Rural Food Processing

Team Cocoyam

Part #	Part Name	Qty	Description	Functions	Material 1	Material 2	Dimensions (mm)	Cost 1	Cost 2
1	Reservoir	1	Reservoir	Hold cocoyam to be dispensed	3D Printed	Metal	280x200x200	$8.27	$67.58
2	Nozzle	1	Nozzle	Directs extruded cocoyam	3D Printed	Metal	50.68x90.68x106.35	$0.84	$7.45
3	Plunger	1	Plunger	Pushes cocoyam through reservoir into nozzle	3D Printed	Metal	193.65x193.65x283.18	$1.78	
4	Roller Base	1	Base, Roller	Base for all rolling operations	3D Printed	Metal	400x82.41x300	$4.55	-
5	Roller Handle	1	Handle, Roller	Provides grip to user to engage in rolling	3D Printed	Metal	250x15.88	$0.50	-
6	Handle Bottom Bracket	1	Bracket, Handle Bottom	Clamps belt to roller bar and provides mounting point for top bracket	3D Printed	Metal	200x41.11x22.23	$0.42	-
7	Roller Bar	1	Bar, Roller	Guides cocoyam through rolling process	3D Printed	Metal	400x15.88	$0.81	-
8	Belt	1	Belt	Provides shaping of cocoyam	Rubber Sheet	Rubber Sheet	200x300	$7.83	$7.83
9	Side Rail	2	Rail, Side	Guides roller bar through motion	3D Printed	Metal	400x46.35x56.35	$1.09	-
10	Belt End Bracket	1	Bracket, Belt End	Clamps end of belt to roller base	3D Printed	Metal	260x125x3.18	$0.71	-
11	Handle Top Bracket	1	Bracket, Handle Top	Connects handle to roller bar	3D Printed	Metal	33.18x70x20	$0.17	-
12	Handle Pin	1	Pin, Handle	Secures handle to top bracket	3D Printed	Metal	40x20	$0.04	-
13	90116A211	12	Screw, M4 x 0.7 mm	Fastener	COTS	COTS	M4 (14mm long)	$12.05	$12.05
14	94205A230	12	Nut, M4 x 0.7 mm	Fastener	COTS	COTS	M4 (5mm tall)	$5.49	$5.49
				Total Cost Estimate:				$44.54	$100.40

Note: Cost 2 has price for 90mx2m sheet, and 1219.2mm long rod which is sufficient for all parts

Sheet metal is also enough to make multiples of each part, meaning total cost overall would be lower

	Link to Cost estimate 1	Link to Cost estimate 2
1	($0.10 per gram) https://nau.edu/library/3d-design-and-scanning/	African weld shop contact
2	($0.10 per gram) https://nau.edu/library/3d-design-and-scanning/	African weld shop contact
3	($0.10 per gram) https://nau.edu/library/3d-design-and-scanning/	https://www.steelsupplylp.com/sku/119871?gclid=EAIaIQobChMI_LDGmPbV5QIVchitBh0CGAtUEAQYBCA
4	($0.10 per gram) https://nau.edu/library/3d-design-and-scanning/	African weld shop contact
5	($0.10 per gram) https://nau.edu/library/3d-design-and-scanning/	https://www.steelsupplylp.com/sku/119871?gclid=EAIaIQobChMI_LDGmPbV5QIVchitBh0CGAtUEAQYBCA
6	($0.10 per gram) https://nau.edu/library/3d-design-and-scanning/	African weld shop contact
7	($0.10 per gram) https://nau.edu/library/3d-design-and-scanning/	https://www.steelsupplylp.com/sku/119871?gclid=EAIaIQobChMI_LDGmPbV5QIVchitBh0CGAtUEAQYBCA
8	https://www.grainger.com/product/E-JAMES-Neoprene-Rubber-Sheet-1MXC8	https://www.grainger.com/product/E-JAMES-Neoprene-Rubber-Sheet-1MXC8
9	($0.10 per gram) https://nau.edu/library/3d-design-and-scanning/	African weld shop contact
10	($0.10 per gram) https://nau.edu/library/3d-design-and-scanning/	African weld shop contact
11	($0.10 per gram) https://nau.edu/library/3d-design-and-scanning/	African weld shop contact
12	($0.10 per gram) https://nau.edu/library/3d-design-and-scanning/	https://www.steelsupplylp.com/sku/119871?gclid=EAIaIQobChMI_LDGmPbV5QIVchitBh0CGAtUEAQYBCA
13	(50 per pack) https://www.mcmaster.com/90116a211	(50 per pack) https://www.mcmaster.com/90116a211
14	(50 per pack) https://www.mcmaster.com/94205a230	(50 per pack) https://www.mcmaster.com/94205a230

8.5 Appendix E: Other Resources Utilized Through Project

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