

Design, Fabrication and Test Performance of a Multi-Crop Grating Machine¹

Orley G. Fadriquel²

ABSTRACT

The objective of this study is to design, fabricate and test the performance of the Multi-Crop Grating Machine. The multi-purpose grating machine was composed of four major components, namely: the hopper/feeding assembly, the grating and the power units, and the machine frame or support. The over-all dimension of the machine measured 300 mm in length, 300 mm in width and 1000 mm in height. In testing the machine, two types of grating blades, the coarse and the fine ones were used. The capacity of the machine in grating cassava using the coarse blade was 161 kg/hr and that for the fine blade was 107. While the grating of papaya requires the machine's capacity of using the coarse blade for 71.43 kg/hr, that for the fine blade was 68.96. The grating of ginger showed that the capacity of the machine of using the coarse blade was 111.11 kg/hr, that for the fine blade was 80.54. To determine the viability of the machine economic analysis was made using the Internal Rate of Return. Results show that an investment for the multi-purpose grating machine is profitable. The grating machine designed, fabricated and performance tested is found to be useful to the cassava, papaya and ginger processors because it lessen the time in grating the commodities.

Key words: grating machine, cassava grater, papaya grater, ginger grater, multi-crop grater

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² Assistant Professor II; Mechanical Engineer; Faculty, College of Engineering and Technology, RSU

INTRODUCTION

During my high school days, my mother occasionally would ask me to do the favor of grating cassava for cassava cake and sometimes of papaya for pickled papaya to augment our income. I would always obey her in exchange for bigger allowance for the following school days. Grating would require me more than two hours to finish half sack of cassava while grating papaya would just enable me to spend enough time but after the grating session, my arms could not be moved easily for aches caused by manual grating.

Ginger rhizome, commonly known as “luya”, is a common morning drink in exchange for coffee for those who are health-conscious. The traditional process to make ginger rhizome tea is to boil pieces of peeled and washed ginger rhizome and after boiling it for several minutes, it could be served together with boiled “camote” or cassava.

Nowadays, cassava is still being processed as cakes, “suman”, “bibingka” and “sago” and being used and explored as source of starch, flour and feeds. Its demand is bound to increase in the years to come. “Papaya”, on the other hand is still processed as pickles because it adds palatability to lechon and other fried foods. “Luya” is being processed as tea labeled and attractively packaged, can be found in many stores.

Commercial instant “salabat” is also processed by grating the ginger rhizome, which is squeezed later to extract the juice. The juice will then be mixed with sugar and simmered until it dries. From that of course, comes the source of instant “salabat”. In most parts of the Philippines, crops earlier pointed out have evolved from being sources of human food to key commercial crops with high-value and marketable products.

Commercial production with sufficient and sustained volume of this type of products will surely give economic impact to the community, therefore, more researches and development interventions must be pursued so as to enhance production from planting to processing.

Grated cassava products, pickled papaya or “atsara” and instant ginger rhizome or “salabat” are the products commonly processed by self employed women to earn income for the family. Even working mothers are engaged in this type of business to earn extra income. These women activities which add economic stability to the family and to the community must be enhanced. Interventions should be continuously pursued with full integration of all efforts from crop production to products.

The facts mentioned have encouraged the researcher to conceptualize the design, fabrication and test the performance of the multi-purpose grating machine to help ease the burden of food processors in grating cassava, papaya and ginger rhizome.

OBJECTIVES OF THE STUDY

This study was conducted to design, fabricate and test the performance of the multi-purpose grating machine conducted at Romblon State University, Odiongan, Romblon during the school year 2009 – 2010. Specifically, the objectives of the study are:

1. To design the components of the multi-purpose grating machine such as the hopper/ feeding chute, the grating and the power units and the frame.
2. To fabricate the multi-purpose grating machine based on the design parameters as the:
 - a. Hopper
 - b. Feeding chute
 - c. Grating Unit
 - d. Power Unit
 - e. Frame
3. To test the performance of the machine in terms of production output using three crops namely cassava, papaya and ginger rhizome.
4. To determine the economic viability of the machine if used commercially.

CONCEPTUAL FRAMEWORK

The conceptual model of the study is shown in the form of a paradigm in figure 1. It utilizes the input, throughput and output approach. The INPUT of the study consisted of alternative ideas from related literature and studies, supplies and materials, tools and equipment and cost of construction of the project. The THROUGHPUT covers the different processes involved in the development of the model namely: designing, fabrication and testing. The OUTPUT is the completed Multi-purpose Grating Machine.

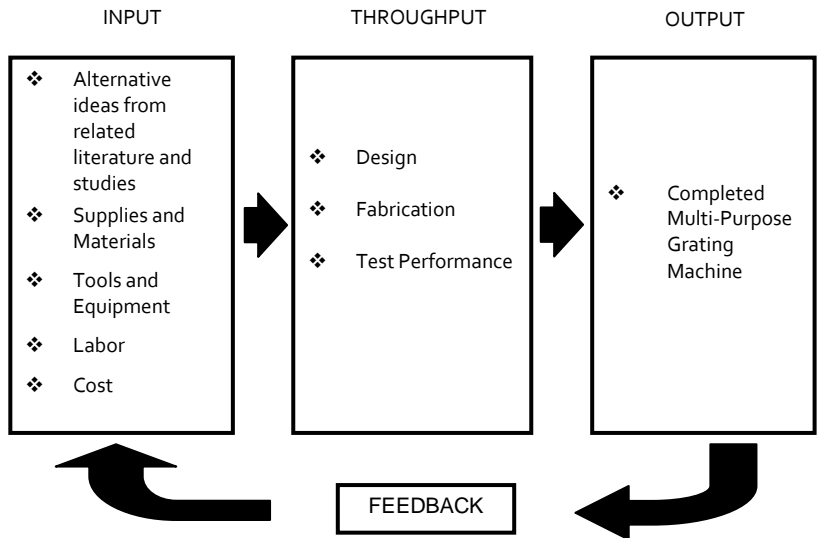


Figure 1. Conceptual Framework

MATERIALS AND METHODS

Materials

Table 1. Materials used in the project

Quantity	Unit	Description
1	Full sheet	Stainless sheet (8 mm thick)
1	Full length	Mild steel 1 x 3/16 x 20 Angle bar
1	Full length	Mild steel 1 x 3/16 x 20 Flat bar
1	Pc	V-belt B-23
¼	Kg	Tying wire
1	Pc	Hacksaw blade (Sandflex)
1	Kg	Electrode gauge 12
1	Kg	Stainless Electrode gauge 12
4	Pcs	3/8 x 1 ½ Bolts
2	Pcs	1/2 inch Nuts
2	Pcs.	1/2 inch Nuts (Stainless)
1	Pc	3/4" ID Pillow block
1	ft	3/4" Ø stainless steel shaft
2	Pcs	Nut washer
2	pcs	Nut washer (stainless)
1	Pc	4x13x1 pulley
1	Pc	1 hp single phase electric motor
1	can	Spray paint no.36 silver(300 ml)
3	pcs	Sandpaper (No. 120)

Tools and Equipment Used

Electric arc welding machine
Rubber mallet
Hammer
Gas welding machine
Grinding machine
Sheet metal cutter
Hacksaw
Anvil
Sandpaper
Bench tools (long nose, fliers, vise grip, screwdriver, wrenches)
Molder

Fabrication Procedure

The fabricate procedure of the multi-purpose grating machine was presented in detail but it is necessary to procure all the supplies and materials needed in the fabrication of the machine. Shop tools and equipment must also be prepared. It is also necessary to contact first an expert welder for labor before fabrication commences.

1. The Frame
 - a. Measure and cut the pieces to the required dimension.
 - b. Assemble the frame. Use an electric arc welding in joining the angle bars.
 - c. Grind the protruding welded parts of the frame with a portable grinder.
 - d. Use file to grind the protruding parts that are not removed by the grinder.

2. The Hopper/ Feeding Assembly
 - a. Measure and cut the sheet with a tin cutter.
 - b. Form the necessary cylinder for the hopper and for the feeding chute.
 - c. Solder the hopper cylinder.
 - d. Solder the feeding chute cylinders.
 - e. Measure and cut a separate sheet for the feeding chute support.
 - f. Measure, cut and round the necessary size of the flat bar.
 - g. Solder the feeding chute to the feeding support.
 - h. Grind the protruding soldered parts.
 - i. Use sandpaper for a smooth finish.

3. The Grating Unit
 - a. Measure and cut the sheet with a tin cutter.
 - b. Weld the nut at the center. The nut will act as the holder of the blade to the shaft.
 - c. Nail punch the bottom to make grating blade at the top portion. The protruding parts will act as the grating blade.
 - d. Grind using electric grinder and sandpaper the protruding parts but make sure that the nail punched protruding parts are not included in grinding.

4. The Shaft
 - a. Using lathe machine, make a screw at one side of the shaft. The screw will hold the nut mounted at the grating blade.
 - b. On the other side of the shaft, make a hole that will then hold the bigger pulley.
 - c. Insert the pillow block in the shaft using hydraulic press.
 - d. Insert the bigger pulley.
 - e. Assemble and weld the shaft to the frame.
 - f. Grind the welded parts for smooth finish.

5. The Catch Basin
 - a. Measure and cut the sheet with a tin cutter.
 - b. Make a center hole to accommodate the passage of the shaft.
 - c. Lay out the catch basin.
 - d. Weld the catch basin to the main frame just above the pillow block of shaft. Make sure proper angle is observed for ease sliding of the grated cassava to the collection box.
 - e. Grind using electric grinder and sandpaper.

6. The Power Unit
 - a. Measure the distance of the two pulleys.
 - b. Lay out the motor.
 - c. Screw the motor to the frame.
 - d. Assemble the switch to the main frame.
 - e. Make sure electric wirings are in place.
 - f. Connect the male plug to the wire.

7. Cover
 - a. Top cover
 - i. Measure and cut the sheet with a tin cutter.
 - ii. Grind using sandpaper to ensure smooth finish to avoid scratches when holding the cover.

- iii. Weld the makeshift hinge to the cover and the hopper cylinder.
 - iv. Weld the wire that will act as holder to the top cover.
 - b. Side cover
 - i. Measure and cut the sheet with a tin cutter.
 - ii. Grind the sides using sandpaper.
 - iii. Weld the sheet to the main frame.
 - iv. Grind using electric grinder the welded parts.
- 8. Finishing
 - a. Grind using sand paper all the rough surfaces of metal.
 - b. Use number 120 sand paper.
 - c. Spray the welded parts with a silver paint to avoid accumulation of rusts. Spray the whole body.

Testing Procedure

In testing the grated commodities, the researcher used two types of blade, the rough blade and fine blade to determine which blade is fitted to the purpose of grating. The diameter of the punched hole for fine blade is half the size of the rough blade. Rough blade has a diameter of 5 mm while the fine blade has 2.5 mm diameter.

- 1. Cassava
 - a. Peel the cassava tubers.
 - b. Wash the cassava tubers.
 - c. Weight the cassava tubers.
 - d. Put the tubers in the feeding chute.
 - e. Switch on the power and push the timer simultaneously.
 - f. Record the time consumed in grating the cassava.
- 2. Papaya
 - a. Peel the papaya.
 - b. Cut the papaya lengthwise into three.
 - c. Remove the seeds.
 - d. Wash the papaya.
 - e. Weight the papaya.
 - f. Slice the papaya in order to fit to the chute.
 - g. Put the papaya in the feeding chute.
 - h. Switch on the power and push the timer simultaneously.
 - i. Record the time consumed in grating the papaya.

3. Ginger rhizome
 - a. Wash the ginger rhizome roots thoroughly using brass to remove soil.
 - b. Weight the ginger rhizome roots.
 - c. Put the roots in the feeding chute.
 - d. Switch on the power and push the timer simultaneously.
 - e. Record the time consumed in grating the ginger rhizome roots.

Note: The procedure was repeated for all the commodities in five replications and blades were cleaned every after testing.

Data Analysis

The result of the test was tabulated and analyzed using the average method. In each type of blade used, actual time recorded per batch of feeding was summarized and divided by the number of replications made.

Economic Analysis

To determine the extent of the project's viability and that of the machine used for commercial purposes the five basic methods for making economic analysis were used: annual, present and future worth methods, Internal Rate of Return and the External Rate of Return.

To establish data needed for the financial analysis, the proponent conducted interview to food processors in the municipality of Odiongan. It was found out that only one food processor used machine in grating cassava. No data were established for ginger and papaya processors using grating machine because there's no available grating machine for such crops.

Other data gathered:

Grating fee	₱ 10.00 per kg
Average mass of cassava grated per day	15 kg/day
Average of operating days/month	20 days/month

Other assumptions

- Prevailing bank interest rate 21% per annum
- Straight Line method was used to determine depreciation cost
- Maintenance cost was ten percent (10%) of the investment cost.
- The salary of machine operator was assumed to be ₱1,500.00 per month since operation of the machine was 8.4 minutes/ day only.

- Life span of the machine is estimated to be 5 years only.
- It was assumed that the investment capital of P15,000.00 was borrowed payable in uniform annual repayment within 5 years.
- Power cost was computed based on the prevailing price of P 8.50 per kW-hr of the Tablas Island Electric Cooperative, that only 36.24% was for generation charge and the remaining 63.76% were for other charges.
- It is assumed that the machine has zero salvage value after five years.

The Machine Components

In the first stage of the conceptualization of this research, the researcher determines the size of the components of the machine. The size of the machine was based on size of the crops to be grated. The chute was first designed to hold six cassavas each having 3 inches in diameter. From there, other components were designed. The proponent also decided to determine what materials are available in the market.

During the conduct of this research, the only available pulley in the market was for B-type belt. The researcher decided to use the same type of pulley. As indicated in the motor plate, the rpm of 1 hp motor is 1730 rpm. The proponent also decided to use a 2-inch pulley for the motor. From the interviews conducted to food grinder machine operators in Odiongan market, most of them said that the average rpm of the food grinder machine ranged from 800 to 900 rpm, so the researcher decided to use 850 rpm for the grater. To determine the size of pulley to be used in the grater shafting, the following formula shown below was used:

$$n_1 D_1 = n_2 D_2$$

where: n_1 – rpm of motor = 1730 rpm
 D_1 – size of the motor pulley = 2 inches
 n_2 – desired rpm of the grater = 850 rpm
 D_2 – size of the shaft pulley = inches

$$D_2 = \frac{N_1 D_1}{N_2} = \frac{(1730 \text{ rpm})(2 \text{ inches})}{850 \text{ rpm}} = 4.07 \text{ inches} \approx 4.0 \text{ inches}$$

The shaft is the major component of the machine since it carries the load for grating therefore proper sizing is necessary.

To determine the size of the shaft, the researcher referred to the Phil. Society of Mechanical Engineers Code (PSME), p.18, equation 5b, for

line shafts carrying pulleys, assuming that transmission losses is neglected and on dead load based.

$$D_s = \sqrt[3]{\frac{53.5 P}{n_2}}$$

where:

P = the power delivered by motor in horsepower. It is also the

power received by the shaft in which the blade and the driving pulley are connected

D_s = the shaft diameter in inches

n_2 = the rpm of the shaft where the blade is fastened

$$D_s = \sqrt[3]{\frac{53.5 (1)}{(850)}}$$

$$D_s = 0.39 \approx 0.5 \text{ in}$$

The belt used was the open belt, B-type.

To proportion the frame of the motor support to the multi-purpose grating machine frame, the researcher decided to use the shortest open type, V-belt, and it was B-23, with actual length of 25 inches.

The center to center distance of the belt will determine the distance between the shaft of motor and shaft of the grater. To determine the center to center distance, the formula as illustrated below was used:

$$L = 1.57 (D_2 + D_1) + 2C + \frac{(D_2 - D_1)^2}{4C}$$

Rearranging the equation, and substituting the other values, the center to center distance was:

$$C = 7.71 \text{ inches} = 196 \text{ mm}$$

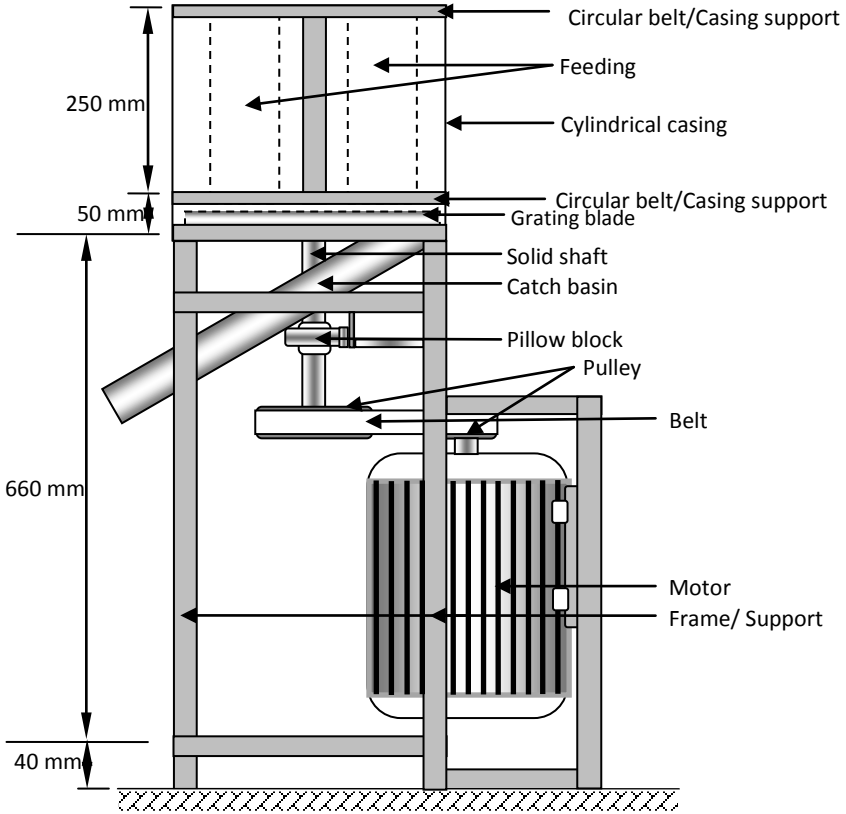
RESULTS AND DISCUSSION

Major Components of the Cassava Grater Machine

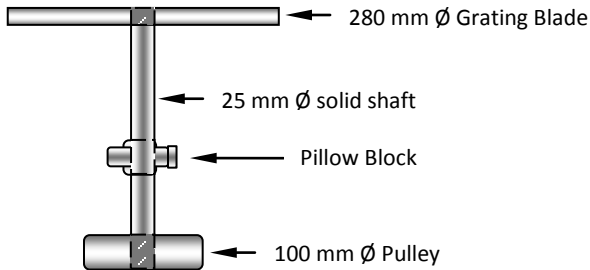
The Hopper/ Feeding Assembly. The Hopper is 300 mm Ø cylindrical drum that holds the 76 mm Ø cylindrical feeding chute. It is made of stainless sheet 8 mm thick, reinforced with a flat bar and is attached permanently to the main frame. It is designed mainly to hold peeled cassava tubers while the operator feeds tubers singly through the feeding chute. The

feeding chute is incorporated into the hopper assembly which is also supported by a belt made of a rounded flat bar.

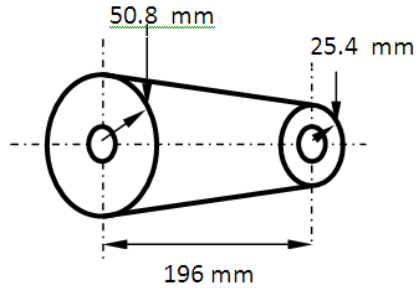
THE WORKING DRAWING



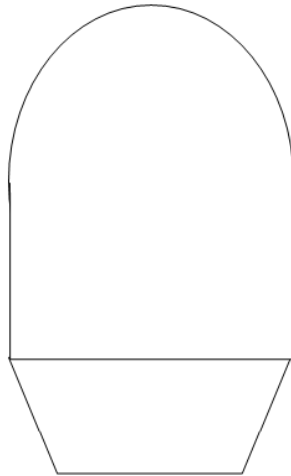
SIDE VIEW OF THE PROJECT



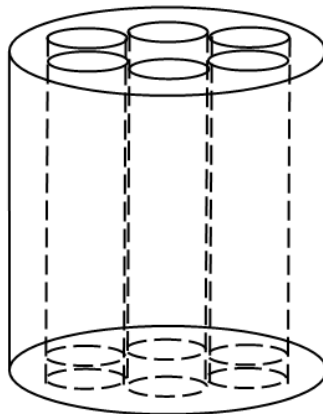
THE GRATING ASSEMBLY



THE BELT AND PULLEY

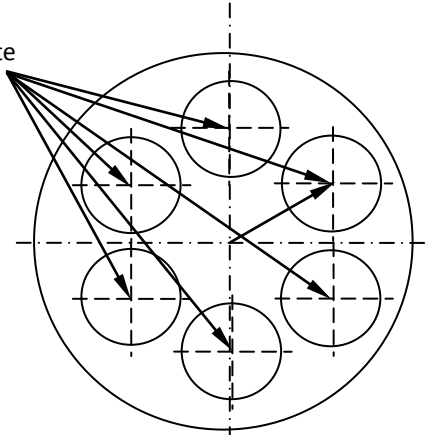


THE CATCH BASIN

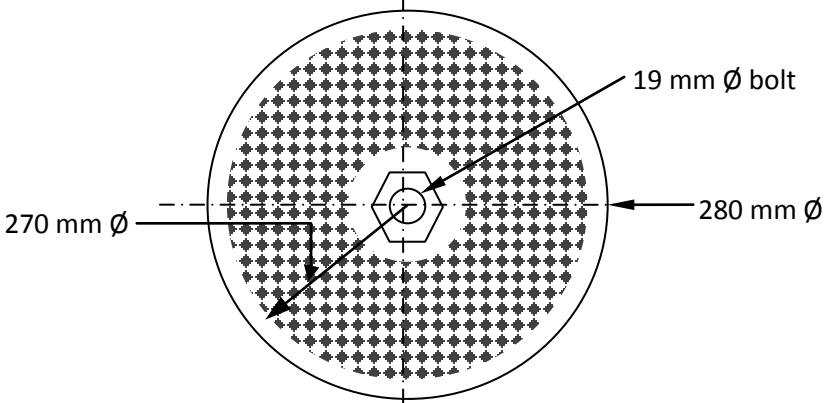


THE HOPPER/ FEEDING CHUTE

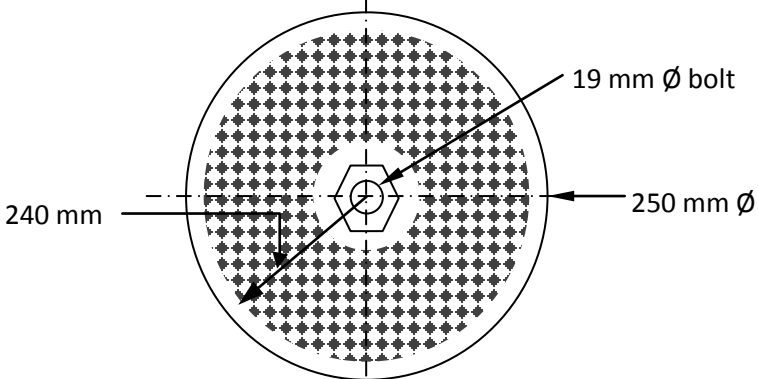
76 mm \varnothing chute



TOP VIEW OF THE HOPPER/ FEEDING CHUTE



THE GRATING BLADE (COARSE)



THE GRATING BLADE (FINE)

The Grating Unit. The grating unit is a circular case housing the rotor plate and the grating blade. It extends downward towards an inclined catch basin which allows the grated cassava to slide and drop into a collection box. The grating blade is mounted to the shaft connected to a motor being driven by pulley and v-belt is also supported by bolts and nuts for easy assembly and dismantling, and for easy access for cleaning. The rotor plate 280 mm Ø is made of 8 mm thick stainless sheet while the grating blades are from a nail-punched hole at the bottom thereby creating the grating blade in the upper portion of the rotor.

The Power Unit. The power unit consists of an electric motor, v-belt and pulleys. The electric motor with shaft pulley of 2-inch Ø and another one of 4-inch Ø has 1 horsepower capacity. Such motor is the prime mover of the machine and also serves as the means through which the belt transmits power to the shaft. The computed size of the shaft is 0.5 inch in diameter, but since the shaft was threaded to hold the grating unit, ¾ inch was used. The researcher used the open (Type B) v-belt.

Machine Frame. The machine frame that measures 300 mm x 300 mm x 700 mm carries the components of the machine. The frame is made of 1" x 1" x 20' angle bar. The joints are shielded metal arc welded to insure strength of the joints.

Machine Cost

The total project cost of the completed grating machine was based on the expenditures for supplies and materials, labor and other expenditures summarized below.

Table 3. Project Cost (Php)

Bill of Materials for Fabrication	8,168.00
Contract Labor (cutting, laying-out and welding)	2,500.00
Research of Related Literature and Studies and other data	750.00
Supplies and Materials (encoding, printing, editing)	250.00
Incidental Cost	1,332.00
Administrative Cost	2,000.00
TOTAL PROJECT COST	15,000.00

The total cost of the Multi-purpose grating machine amounted to P15,000.00 as shown in Table 3 but the labor cost was computed based on the actual verbal contract with the laborer. Production cost per unit could be minimized however if mass production will be undertaken.

Machine Performance

Cassava grating. Ten kilograms of medium sized peeled cassava were tested in the machine and were divided into 5 batches, with 2 kilograms each batch placed inside the feeding chute. Each batch was placed inside the feeding chute. Clock is started simultaneously as the switch is “on” and the test was repeated for other batches with the following results below:

Table 4. Machine performance in grating cassava (2 kg)

Batch (2 kg each)	Coarse Blade (time)	Fine Blade (time)
1	47 seconds	69 seconds
2	43 seconds	67 seconds
3	45 seconds	65 seconds
4	45 seconds	69 seconds
5	44 seconds	67 seconds
Average time	44.8 seconds	67.4 seconds

The result shows that 2 kilograms of cassava can be grated with an average time of 44.8 seconds using the coarse blade with the machine’s capacity of using the coarse blade.

$$\frac{2 \text{ kg}}{44.8 \text{ sec}} \times \frac{3600 \text{ sec}}{\text{hr}} = 161 \frac{\text{kg}}{\text{hr}}$$

On the other hand, 2 kg of cassava can be grated with an average time of 67.4 seconds with the machine’s capacity of 107 kg/hr using the fine blade.

$$\frac{2 \text{ kg}}{67.4 \text{ sec}} \times \frac{3600 \text{ sec}}{\text{hr}} = 107 \frac{\text{kg}}{\text{hr}}$$

As can be noted, the result of the test conducted differs since the coarse blade has greater capacity than the fine blade.

Papaya Grating. A ten-kilogram big-sized peeled papaya was tested in the machine. Such papaya was divided into 5 batches with each batch weighing 2 kg placed inside the feeding chute. Simultaneously, time was started as the switch is “on” and such test was repeated for other batches with the results shown in Table 5. The result shows that 2 kilograms of papaya can be grated with an average time of 1.68 minutes using the coarse blade with the machine’s capacity of 71.43 kg/hr using the coarse blade.

$$\frac{2 \text{ kg}}{1.68 \text{ min}} \times \frac{60 \text{ min}}{\text{hr}} = 71.43 \frac{\text{kg}}{\text{hr}}$$

Table 5. Machine performance in grating papaya (2 kg)

Batch (2 kg each)	Coarse Blade (time)	Fine Blade (time)
1	1.70 minutes	1.76 minutes
2	1.72 minutes	1.83 minutes
3	1.65 minutes	1.80 minutes
4	1.63 minutes	1.78 minutes
5	1.71 minutes	1.75 minutes
Average time	1.68 minutes	1.74 minutes

On the other hand, 2 kg of papaya can be grated with an average time of 1.75 minutes using the coarse blade but for the fine blade, the capacity of the machine is 68.96 kg/hr.

$$\frac{2 \text{ kg}}{1.75 \text{ min}} \times \frac{60 \text{ min}}{\text{hr}} = 68.96 \frac{\text{kg}}{\text{hr}}$$

Ginger Rhizome Grating. A ten-kilogram medium-sized washed ginger rhizome was also tested in the machine and such was divided into 5 batches, with each batch weighing 2 kg placed inside the feeding chute. Simultaneously, time was started and such test was also repeated for other batches. Results are as follows:

Table 6. Machine performance in grating rhizome (2 kg)

Batch (2 kg each)	Coarse Blade (time)	Fine Blade (time)
1	1.0 minute	1.43 minutes
2	1.2 minute	1.45 minutes
3	1.3 minute	1.55 minutes
4	0.9 minute	1.4 minutes
5	1.0 minute	1.63 minutes
Average time	1.08 minutes	1.49 minutes

The result shows that 2 kilograms of ginger rhizome can be grated with an average time of 1.08 minutes using the coarse blade with the machine's capacity of 111.11 kg/hr.

$$\frac{2 \text{ kg}}{1.08 \text{ minutes}} \times \frac{60 \text{ minutes}}{\text{hr}} = 111.11 \frac{\text{kg}}{\text{hr}}$$

On the other hand, 2 kg of ginger rhizome can be grated with an average time of 1.49 minutes using the fine blade having the machine's capacity of 80.54 kg/hr using the fine blade.

$$\frac{2kg}{1.49 \text{ minutes}} \times \frac{60 \text{ minutes}}{hr} = 80.54 \frac{kg}{hr}$$

As noted, the result of the test conducted differs since the coarse blade has a greater capacity than the fine blade.

The Power Consumption

The motor is rated at 1 horsepower or equivalent to 0.746 kW. According to the Tablas Island Electric Cooperative, the prevailing price of electric power is P8.50/kW-hr. If the machine will run in 1 hour, the power consumption will be P6.34, as the computation shows:

$$0.746 \text{ kW} \times hr \times \frac{P8.50}{\text{kW} - \text{hr}} = P 6.34$$

Economic Analysis

Using the five basic methods for making economic analysis to determine the extent of the projects' viability, the Annual Worth Method showed that an investment would have a profit of P3,153.92 annually. The Present Worth Method showed that the present worth of an investment is P24,228.32, higher than the initial investment. The Future Worth Method showed that the net future worth was P210,370.97 much greater than the future worth of investment amounting to just P38,906.14. The Internal Rate of Return Method showed that the internal rate of return for an investment was 47.96% higher than the 21% prevailing bank interest, while the External Rate of Return Method showed that the external rate of return is 69.5% much higher than the 21% prevailing bank interest.

The five methods used in determining the viability of a project indicated that an investment for the multi-purpose grating machine is profitable.

SUMMARY AND CONCLUSION

The grating machine designed, constructed and performance tested is found to be useful especially to the cassava, papaya and ginger processors because it lessen the time in grating the commodities. The multi-purpose grating machine that measures 300 mm x 300 mm x 1000 mm is composed of four major components, namely the hopper/ feeding assembly, the grating and the power units, and the machine frame or support. It is powered by a 1-hp electric motor and can grate cassava with an average capacity of 134 kg/hr, grate papaya with 70.195 kg/hr and can grate ginger with an average

capacity of 95.83 kg/hr. As noted, the results of the tests conducted differed because the coarse blade has greater capacity than the fine blade. In the economic analysis, the five methods used in determining the viability of a project indicated that an investment for the multi-purpose grating machine is profitable.

The multi-purpose grating machine is beneficial to food processor because the grating of different crops is much easier and faster than the manual grating. It was found out that an investment of P15,000.00 was viable for the project.

IMPLICATIONS AND RECOMMENDATION

Based on the findings and conclusions previously stated, the following courses of action have been recommended:

1. That the designed, fabricated and performance tested multi-purpose grating machine be used for the purpose.
2. That the designed, fabricated and performance tested grating machine be extended to the community especially to the identified areas where cassava, papaya and ginger are abundant.
3. That the designed, fabricated and performance tested grating machine be commercialized.
4. That test using other commodities like potato, arrow roots, carrots, gabi, sweet potato, and other root crops be conducted.

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