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Enhancing Value and Efficiency in Calamansi and Banana Processing: A Study on Waste Utilization and Chopping Machine Development

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ABSTRACT

Mindoro Island is renowned as the "Calamansi King" and "Banana King" in the Philippines. However, the traditional manual slicing method employed during the processing of these commodities proves to be time-consuming, laborious, and taxing on the wrists and arms of workers. Thus, the study aimed to develop a specialized chopping machine for efficiently processing Calamansi peel and rag, as well as banana pulp for making banana chips. The experiment utilized Banana pulp, Calamansi peel, and rags as test materials, subjecting them to different speeds (573, 1146, and 1720rpm) using a completely randomized design (CRD). The results demonstrated that the highest shredding input capacity of 105.54 kg/hr was achieved at a shaft speed of 1720rpm, boasting an impressive 94.55% chopping efficiency. However, the machine faced inefficiencies due to the amount of crushed chip materials and had an energy demand of 0.372 kW-hr/kg. The chipped product exhibited a vertical orientation with a 1mm thickness. Cost analysis revealed that the machine needed to process a total of 16,832.67 kg of bananas at a custom rate of Php2/kg to break even. Remarkably, the machine could generate an additional income of Php260,154.86/yr for processors, with a 0.4-year payback period and a 209.78% rate of return, making it a highly cost-efficient device. By introducing this innovative chopping machine, Mindoro Island's processing of its flagship commodities can be significantly improved, reducing manual labor, enhancing efficiency, and offering greater economic benefits to the processors..

INTRODUCTION

Banana and Calamansi were recognized as the flagship commodities of Mindoro Island, earning the island the titles of "Calamansi King" and "Banana King" in the Philippines. In 2019, the Philippines recorded a significant volume of calamansi production, reaching approximately 126 thousand metric tons. Additionally, the production value of calamansi in the country amounted to around 2.6 billion Philippine pesos during the same year (PSA,2020). However, according to SEARCA, only 30 – 35 percent was collected or used during the processing of the Calamansi fruit, while the remaining 70-75 percent (weight basis) was considered product waste. Only the pulp was squeezed and the juice was collected, while the seeds, peels, and rags were discarded. Based on the annual production volume of Calamansi, the accumulated waste amounts to a range of 88,200 to 94,500 metric tons per year, with the majority of this waste often ending up in landfills. This leads to air and water pollution and represents an economic loss for Calamansi farmers. Nevertheless, Calamansi waste offers significant health benefits as it can be processed and sold to manufacturers or directly to the public market as a high-value functional ingredient. In response to this, public agencies such as the Department of Science and Technology and non-government organizations are continuously developing Calamansi by-products, especially those derived from the waste of Calamansi fruit after the juice is harvested or collected.

One of the Calamansi by-products utilized from the Calamansi waste is the drying of Calamansi Peel and rag. This developed product is highly beneficial not only for consumers but also for Calamansi farmers in the country, particularly in the MIMAROPA region. However, given the climate of Mindoro, where rainfall is often experienced even during the summer season, it is more ideal to chop the Calamansi peel and rag prior to drying. This approach results in faster drying of the product, as the reduced or chopped form allows for quicker moisture evaporation.

On the other hand, there is a high demand for banana chips, where unripe fruit is sliced or chipped and then fried, on Mindoro Island. Based on interviews, processing centers in Oriental Mindoro still rely on knives and/or peelers to slice or chip the pulp of the Cardava variant or "Saba" banana before frying. This manual process is time-consuming, laborious, and causes strain on the wrists and arms of the workers. According to banana chips processors, some slicers are available in the market. However, since these slicers were not specifically designed for banana chipping or slicing, the resulting chips were observed to be thicker than the usual slice of banana chips (1-4mm). This variation in thickness can impact the preparation and marketability of the product. Moreover, the existing locally available chippers follow a cross-sectional slicing pattern or cut across the length of the banana pulp, while the processors prefer vertical slicing or along the longer section of the banana pulp. Additionally, some of the available slicers are not made from food-grade materials, raising concerns about the hygiene and safety of the final product.

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Therefore, this study aims to develop a versatile chopping machine capable of efficiently slicing or chipping Calamansi peel and rag, as well as banana pulp for banana chip production.

Objectives of the Study

The general objective of the study was to develop a chopping machine for Calamansi peel and rag, and banana chips making. Specifically, the study aimed to:

1. design a Calamansi peel and rag, and banana chipper machine using locally available materials;
2. fabricate the machine using local manufacturing technology;
3. evaluate the performance of the device in terms of chipping capacity and chipping efficiency;
4. determine the energy demand of the device; and,
5. analyze the cost of using the machine.

LITERATURE REVIEW

Calamansi Peel and Rag

Recognized for its versatility, calamansi holds great significance as one of the most important citrus fruits in the Philippines. In 2020, the Philippine Statistics Authority (PSA) reported a calamansi production of 126,000 metric tons (MT) in the country.

This fruit finds extensive use in commercial processing, including the production of bottled concentrates, ready-to-drink juices, and serving as a primary ingredient in cleaning and cosmetic products. It is also a kitchen essential, known for enhancing the flavors of various dishes and utilized in creating dips and sauces like toyomansi. However, despite the numerous applications of this small fruit, only a mere 30-35 percent is utilized, with the remainder being considered as waste.

In light of this situation, the PSA estimated that the volume of calamansi waste generated in the same year amounted to approximately 81,591 MT. This prevalent issue has piqued the interest of researchers at DOST-ITDI, leading them to embark on a study focused on harnessing the value of calamansi peel, also known as 'pinagbalatan.'

Studies indicate that calamansi peel contains a significant amount of dietary fiber powder, primarily composed of insoluble fiber that offers substantial health benefits. This dietary fiber powder can serve as a functional ingredient in the production of food and health supplements. By utilizing discarded calamansi peels, the study aims to address the problem of oversupply during peak seasons. Farmers can enhance their income by selling the peels for dietary fiber production. Furthermore, the fiber capsules can be used as dietary supplements, or as a partial filler in the production of quick-cook oats and as a substitute for wheat bran (Atienza, 2019).

Banana Chips

Banana Chips in the Philippine Market

Banana chips have emerged as a prominent player in the snack industry, with many market observers suggesting that they can rival the popularity of potato chips in the global market. This surge in demand is attributed to several factors. Firstly, the increasing number of health-conscious consumers actively seeking organic and healthier snack options has contributed to the robust demand for banana chips. Additionally, the irresistible sweetness of the product has been identified as another driving force behind its popularity. Furthermore, the accessibility of a consistent supply and the year-round availability of raw materials have played a significant role in fueling the growth of banana chip demand.

In reality, the demand for a product is influenced by various factors such as supply, cost-effective manufacturing, taste, and shifting consumer behavior. Regardless of the specific reasons, what matters is the end result: the thriving banana chip market, which positively impacts the lives of many Filipino farmers and their families.

The Process of Banana Chip Production

Originating from the Cardava variant, bananas are carefully harvested and transported to both small and large-scale manufacturing facilities. Upon arrival, the bananas undergo a thorough washing process to eliminate any external debris. Subsequently, they are either machine-sliced or sliced manually by personnel. Automation is advantageous for large-scale manufacturers due to its efficiency, while small-scale manufacturers rely on manual labor for this task.

Next, the banana slices are immersed in brine water to prevent oxidation, which can cause discoloration. They are then blanched, de-watered, and subjected to frying. In response to market demands, some manufacturers now offer a baked variant of banana chips, appealing to a wider range of consumers. Once the chips achieve a desirable golden-brown crispiness, they undergo de-oiling and are delicately seasoned. Finally, the mouthwatering banana chips are carefully packaged, labeled, and prepared for delivery to eager customers.

Market Performance

The Philippines stands as one of the leading global producers of bananas, with a remarkable production volume. In 2014 alone, our country contributed 9.2 million tons of bananas, accounting for approximately 6% of the total global banana production. Despite being a significant exporter of bananas, the majority of our locally produced bananas are consumed domestically by Filipinos. Within our local market, approximately 65% of our total banana production is consumed. Out of this share, 16.5% is dedicated to the global banana chips market. Another 45.5% is distributed to wet markets and grocery stores as table bananas, typically consumed raw in households. Approximately 4% of the production is considered as loss, either due to natural causes or assumed to be repurposed as animal feed in farms or households. On the international front, the Philippines exports to 30 countries, with the United States and Europe being the primary customers, importing a significant portion of our banana produce.

When it comes to banana chips, the Mindanao region accounts for 90% of the manufactured by-product.

Notably, our key importers for banana chips include the United States, United Kingdom, Germany, Vietnam, and China, collectively representing 64% of the global banana chips market in 2011. Market observers widely acknowledge the profitability of both the bananas and banana chips markets. Market reports indicate a projected annual growth rate of 10-15% for the banana chips market in the international arena.

Banana Chips Empowering the Community

The thriving banana chips market not only generates substantial revenue for large-scale manufacturers but also presents significant livelihood opportunities for small entrepreneurs. What's truly remarkable is that this profitable market extends its benefits to our local banana farmers and their families. Government reports have highlighted the significant role played by women and children in processing banana by-products, such as banana chips, for sale in local markets, while their husbands diligently cultivate and harvest bananas in the fields. This collaborative effort within the community transforms into a flourishing business venture, uplifting the economic well-being of thousands of families (Greenville, 2019).

Chipping Machine

A size reduction machine, whether powered or manually operated, is employed to effectively cut or slice products into small, thin pieces commonly referred to as chips.

Prior Efforts

The chipper primarily targets laborers and Calamansi and Banana processors in the MIMAROPA region of the country. Private machine manufacturers and fabricators have also shown interest in investing in this machine. The users have emphasized the need for mechanization to minimize manual labor and reduce the time required for processing. The study conducted a comprehensive review of relevant literature and conducted interviews to identify prior efforts related to the subject matter.

Manual Plantain Slicer

The Manual Plantain Slicer is equipped with a stainless-steel blade, specifically designed for slicing plantains and a variety of vegetables. It offers interchangeable blades that allow for different thickness options, ensuring ease and simplicity during the slicing process. According to the interview findings, this type of slicer is widely utilized by banana chip processors in the region.

Figure 1: Manually operated slicer or chipper
Source: Viki's Kitchen, Raj Kamal Engineering

Philippine Agricultural Engineering Standard (PAES) Chipping Machine

The figure below depicts a sample design of a motor-driven chipping machine developed for PAES standardization. This design was adopted from the American Society of Agricultural Engineers (ASAE).

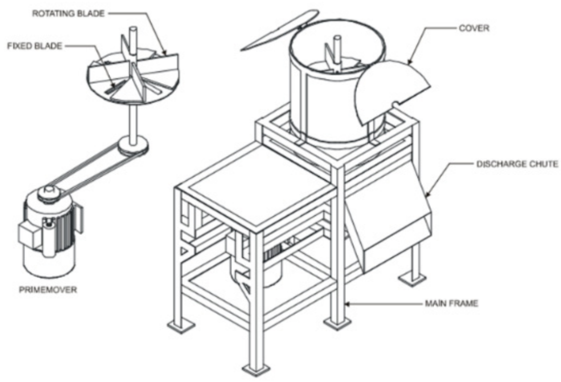

Figure 2: Typical design of a chipping machine
Source: Philippine National Engineering Standard

Design and Development Of Power Operated Banana Slicer For Small Scale Food Processing Industries

A power-operated rotary banana slicer, designed specifically for small-scale processing, was developed based on the engineering properties of banana varieties, such as Nendran and Dwarf Cavendish. This slicer comprises feeders for round slicing, a cutter, a power transmission mechanism, a base support, and a frame. Its purpose is to address the limitations of existing hand or power-operated rotary slicers and meet the requirements of small-scale processing industries. With a three-blade cutter operating at a speed of 360 rpm, this slicer achieves a slicing efficiency of approximately 93-94% and an effective capacity of about 100 kg/h for both banana varieties. The mean thickness of the cut is approximately 2.00 ± 0.194 mm, while the mean roundness measures 0.84 and 0.70 for the Nendran and Dwarf Cavendish varieties, respectively (Sonawane *et al.*, 2010).

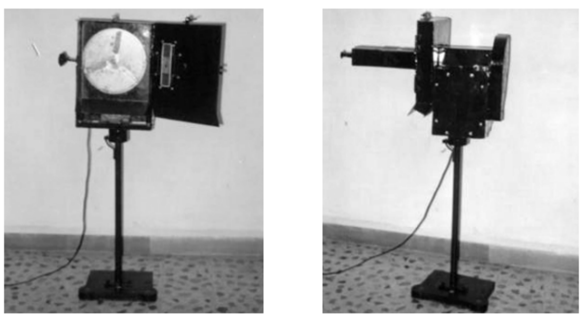

Figure 3: Banana slicing machine (a) front view; (b) side view

Design of Banana Slicing Machine

Banana Chips are widely popular in Malaysia, particularly during the celebration of "Hari Raya," leading to increased demand during this festive occasion. Slicing is a crucial step in the Banana Chips production process, significantly impacting productivity. Manual slicing methods require substantial human effort and consume considerable time. To address this issue and enhance productivity, a Banana Slicing Machine was designed.

The project followed George E Dieter's eight-phase design process, including problem definition, information gathering, concept generation, concept evaluation, product architecture, configuration design, parametric design, and detail design. Existing patents and available machines were studied to generate ideas for the banana slicing machine. The selected idea and concept were then modeled using SolidWorks software, enabling engineering analysis and Life Cycle Assessment (LCA).

The machine's theoretical calculations were also considered in the analysis. Results indicate that the machine can produce 64.8 kg of banana slices per hour. The overall dimensions of the banana slicing machine are 700mm x 600mm x 755mm, with a weight of 57 kilograms (Azhar, 2022).

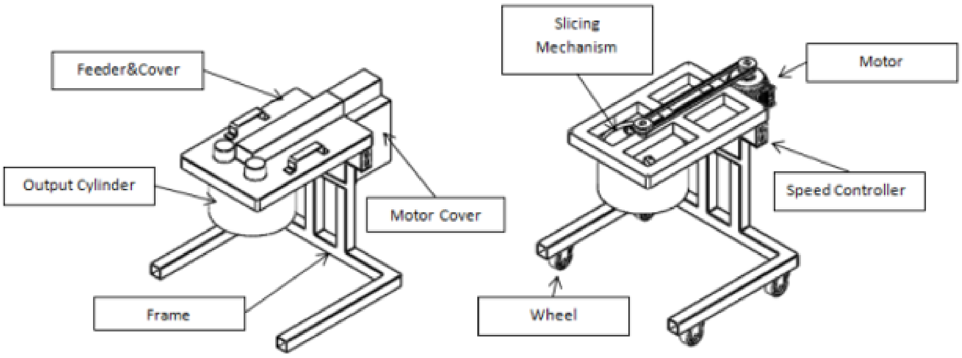

Figure 4: GG-CP305 Commercial Plantain Shredding Banana Chipper Machine

Performance Evaluation of a Manually - Operated Banana Slicer for Small Scale Food Processing Industries

The main objective of this study was to develop and assess a manually operated banana slicer suitable for small-scale food processing industries. The design focused on portability, durability, and safety. The device comprises angle bars, a hand crank, pillow blocks, flange bearings, shafting, bevel gear, cover plate, turntable, cutter blade, and a stainless tube as a feeder or chute.

After developing the prototype, a performance evaluation was conducted, considering capacity, weight of good cuts, weight of rejects, and slicing efficiency. The portable banana slicer's average capacity was found to be approximately 60 kg/h when operated with a two-blade cutter at 120 rpm. Notably, the device's effective capacity increased as the number of blades and cutter plate RPM increased.

The slicing efficiency achieved ranged from 90% to 96% at a cutting speed of 120 rpm. Consequently, it was concluded that using a cutting speed of 120 rpm with a two-blade cutter is optimal, resulting in a capacity of 60 kg/h and excellent slicing efficiency. Moreover, this speed provided the best chip geometry.

By utilizing this manually operated banana slicer, backyard and small-scale banana processing industries are expected to experience improved productivity and product quality. The slicer's efficiency and portability are likely to contribute to enhancing the overall performance of these industries (Namoco and Buna, 2022).

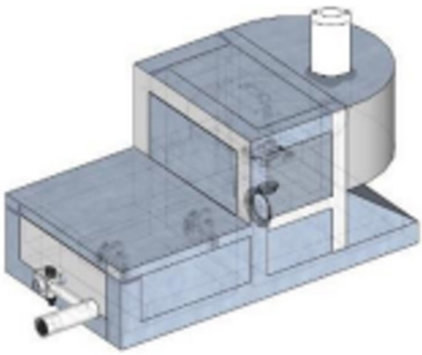

Figure 5: perspective of the Innovative Manually Operated Banana

Chopping Machine Available in The Internet

In the market, there are several available products for banana slicing, but all of them are imported from abroad. Conducting a thorough search of existing products is crucial as it provides valuable information. By reviewing the features and specifications of these products, we can gather valuable insights. This information will prove invaluable in generating new, creative, and innovative ideas for designing a brand-new banana slicing machine. Below is a table comparing a few existing banana slicing machines in the market.

Product Characteristic	Product 1	Product 2	Product 3	Product 4
				
Name	Manual Cutting Machine.	Vegetable Cutter DQ180A	IFC300 Banana Slicing Machine	GG501 Plantain Chips Machine
Made In	China	Malaysia	China	China
Price Range	RM 500-1000	RM 2000-3000	RM 4000-6000	RM 4000-6000
Dimension(mm)	360 x 190 x 430	400 x 290 x 570	540 x 820 x1060	640 x 500 x 840
Weight	8 Kg	25 Kg	90 Kg	75 Kg
Material	Stainless Steel	Aluminium Alloy and Stainless Steel	Stainless Steel	Stainless Steel
Operation	Manual	Semi-automatic	Semi-automatic	Semi-automatic
Power (Watt)	-	250W	750W	750W
Capacity	Depend on Human Energy	50-450Kg/hour	300-600kg/hour	100kg/hour

Figure 6: Chopping machines available in the internet

MATERIALS AND METHODS

Conceptualization of the Study

Problems and suggestions of the target end users were gathered and which will be considered in designing the machine. Existing designs, related literatures, and Philippine standards for agricultural machines were searched to dissect every component of the machine including the proper materials to be used and understand the working principles of the machine. Locally available materials and components were considered for the machine parts.

Figure 7 shows the conceptual framework of the study, following the input-process-outcome method. It was primarily based on the general objective of the study which was to develop a chipper machine for Calamansi peel and rag, and Banana chips making.

INPUT	PROCESS	OUTPUT
1. Literatures, IP search, design considerations, Autodesk Inventor/ Solidworks®	1.Design conceptualization, design analysis, design calculations	1. 2D and 3D Design plan of the Calamansi peel and rag, and banana chipper.
2. Design plan of the machine, licensed manufacturer, locally available materials	2. Fabrication of the machine using local manufacturing technology	2. Chipper machine for Calamansi peel and rag, and banana chips making.
3. Chipper machine for Calamansi peel and rag, and banana chips making.	3.Preliminary Testing, Adjustments, Final Testing and Performance Evaluation	3. Machine operating performance, energy demand and other assumptions
4. Machine operating performance, energy demand and other assumptions.	4. Cost Analysis	4. Machine annual cost, break-even point and payback period

Figure 7: Conceptual framework of the study

Design Concept of The Machine

The key elements of the machine comprise the hopper, blade assembly, power transmission system, prime mover, and frame assembly. To ensure accessibility and cost-effectiveness, all parts and components are constructed using locally available materials. These materials can be fabricated using equipment readily accessible within the local area. The design of the machine focuses on incorporating user-friendly components, prioritizing operator ease, comfort, and safety.

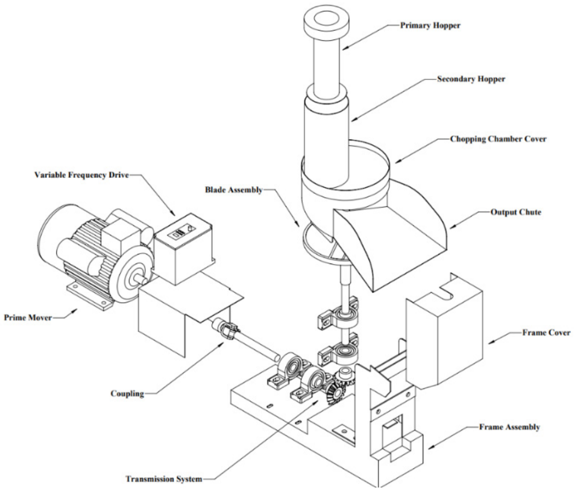

Figure 8: Exploded view of the chopping machine.

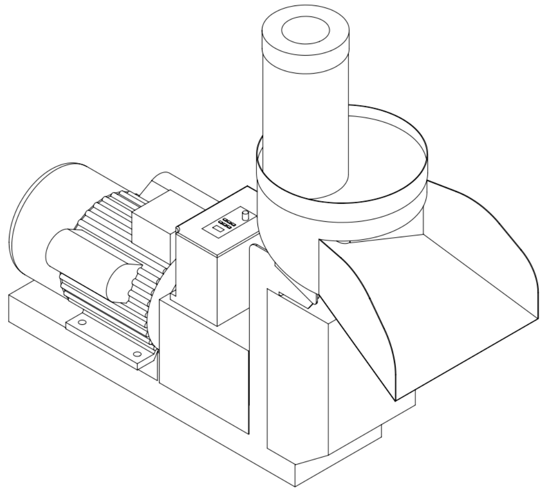

Figure 9: Isometric view of the chopping machine.

Blade Assembly

The blade assembly consists of three cutting blades that are attached to a circular plate using bolts and nuts. This configuration serves the purpose of controlling the product thickness and facilitating easier maintenance of the blades.

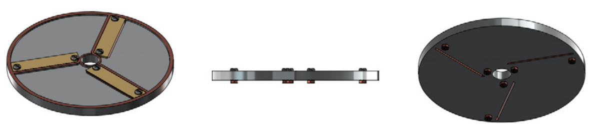

Figure 10: Isometric view of the chopping machine.

The analysis of blade force will be determined by the shearing force required to slice the banana pulp. This force can be calculated using the following formula.

$F_{sh}/A= Sut/(F.O.S.)$ (1)

Where: F_{sh}= shearing force, N

A= Area of contact of blade to the material to be cut, mm^2

Sut= Yield strength of PET bottles, MPa

F.O.S.= Factor of Safety

Shaft Assembly

In designing the machine, a different size of shaft is important factor to consider that depends on the loads that are being applied to it. The diameter will be selected based on the strength of the material and the varying combined twisting and bending moment subjected to it which will be computed as,

$d_o^3= 16/(\tau_d \pi)\ [\sqrt{((C_m \times M_B)^2+ (C_t \times T)^2)}]$ (2)

Where: d_o= diameter of the shaft, mm

τ_d= design shear stress, MPa

C_m= bending factor

M_B= bending moment, N.mm

C_t= torsion factor

T= torque, N.mm

Power Transmission Assembly

To power the rotation of the blade assembly, an electric motor was employed as the prime mover in the machine. The gear box speed reducer, pulleys, and belts used in the machine adhere to the specifications outlined by the Philippine Agricultural Engineering standards (PAES). For the safety of the operator, all rotating parts of the transmission system are adequately covered.

Frame Assembly

The frame serves as the structural framework of the machine, supporting and housing all its components, including the hopper and discharge chute. It has been specifically designed to endure various loads and vibrations during operation. In the component's design, portability and ergonomics have been taken into careful consideration. For the calculation of allowable stress used equation 3.

σ_{Allow}= YS/FOS (3)

Where: σ_{Allow} = Allowable Stress, MPa

YS= Yield Strength or Ultimate strength, MPa

FOS= Factor of Safety

Cost Analysis

It consists of tracing the resource flows induced by an investment from the Chipper fabrication up to its utilization indicating all the necessary financial cost needed from construction to the chipping operation. It includes the fixed cost, variable cost, annual operating cost, net income, payback period and return of investment analysis (Hunt 2001).

Annual Fixed Cost (AFC), Php/yr

AFC= D + I + TIS (4)

Where: D= depreciation cost, Php/yr

I= interest on investment, Php/yr

TIS= Taxes, Insurance and Shelter, Php/yr

Annual Variable Cost (AVC), Php/yr

AVC= FC + R&M + LC + LaC (5)

Where: FC= Electrical Cost, Php/yr

R&M= Repair and Maintenance Cost, Php/yr

LC= Lubrication Cost, Php/yr

LaC= Labor Cost, Php/yr

Annual operating cost (AOC), Php/yr
AOC= AFC + AVC (6)
Where: AFC= Annual Fixed Cost, Php/yr
AVC= Annual Variable Cost, Php/yr
Added annual revenue for using the machine (AAR), Php/yr
AAR= RSP (7)
Where: RSP= Annual total revenue for chopping, Php/yr
Added annual net income (AANi), Php/yr
AANi= AAR – AOC (8)
Where: AAR= Added annual revenue for using the machine, Php/yr
AOC= Annual operating cost, Php/yr
Break-even Point (BEW), Kg/yr
BEW= AFC/(CR-VC/C) (9)
Where: AFC= annual fixed cost, Php/yr
C= Chopping Capacity, kg/hr
VC= variable cost, Php/hr
CR= custom rate, Php/kg
Payback period (Pp), yr
Pp= (IC-SV)/AANi (10)
Where: AFC= annual fixed cost, Php/yr
C= Chopping machine Capacity, kg/hr
VC= variable cost, Php/hr
CR= custom rate, Php/kg
Rate of return (ROR), %
ROR= AANi/AOC x 100 (11)
Where: AANi= added annual net income
AOC= Annual operating Cost

RESULTS AND DISCUSSION

Description of the Machine

The operation of the machine commences when the first test material is introduced into the hopper or inlet chute. The test material then descends into the cutting chamber, where the rotating disc blade assembly is positioned.
The disc assembly consists of three detachable sharpened blades of identical dimensions, evenly distributed on a circular plate. As the test material passes through the blade assembly, the rotation of the circular plate causes the blades to come into contact with the test material, resulting in slicing or chipping of the product. The sliced or chipped product is collected as it exits through the outlet chute, aided by gravitational force.
The machine is driven by a 0.5 horsepower or 372 Watts electric motor, specifically a single-phase motor. Power transmission from the prime mover shaft to the chipper's rotating shaft, where the blade assembly is attached, is facilitated by a set of gear box speed reducer and Variable Frequency Drive. Table 1 presents the specifications of the machine.

Figure 11: Fabricated Chipping Machine.

Table 1: Specifications of the Chopping machine

Particular	**Specification**
Overall Dimensions, mm	
Length	758
Width	260
Height	697
Wight	20kg
Hopper & covers	2mm thickness, Stainless Steel #304
Power Transmission System	
Bevel Gears	15 teeth, AISI 1045, 65.65mm Ø
Pillow Blocks	UCP 205
Chopping Chamber Assembly	
Chopping blades	3 blades, 210mm Ø, 30mm thickness, Stainless Steel #304
Shaft	25mm Ø, 325mm length
Prime Mover	372 watts induction motor (Copper)

Machine Performance	
Chopping Capacity	105.54kg/hr
Chopping Efficiency	94.55%

Machine Performance Evaluation

The machine was evaluated in terms of the capacity, efficiency and energy demand as affected by different speed of the shaft (573rpm, 1146rpm and 1720 rpm). The results were analyzed statistically using Statistical Tool for Agricultural Research (STAR).

Machine Chopping Capacity

It is the ratio of the weight of the input materials less unchipped materials, to the total weight of the input materials to the chopper, expressed in percent determined by the following equation:

$$Cc = Wi/T \quad (12)$$

Where: Cc= Chipping Capacity, Kg/hr
Wi= Weight of Input Materials, Kg
T= Operating Time, hr

Table 2 presents the chopping capacity results based on different shaft speeds. The highest capacity was achieved at the fastest shaft speed of 1720rpm, with an average value of 105.54kg/hr. The second highest capacity was observed at 1146rpm, with a mean value of 68.25kg/hr, while the lowest capacity was recorded at 573rpm with an average value of 67.37kg/hr. The analysis of variance indicated that shaft speed significantly influenced the chopping capacity of the machine at a 5% level of significance. Furthermore, the mean chopping capacity at various shaft speeds showed significant differences, as evident in the comparison among treatment means (Table 2).

The results demonstrate the competitive performance of the machine compared to similar studies conducted by Pandya *et al.*, Namoco *et al.*, and Azhar *et al.*, where the developed machines achieved capacities of 100kg/hr, 60kg/hr, and 64.8kg/hr, respectively. Additionally, the vertical orientation of cutting the banana was observed to affect the capacity of the device. Pre-testing revealed that the machine had a higher capacity when slicing the banana pulp horizontally or in a traverse direction, as opposed to slicing the pulp in a vertical orientation. The machine sliced the banana pulp in a vertical orientation.

Table 2: Mean chopping capacity at various main shaft speed, kg/hr.

Treatment RPM	**Means**
573	67.37 b
1146	68.25 b
1720	105.54 a

**Means with the same letter are not significantly different.*

Machine Chopping Efficiency

It is the ratio of the weight of the input materials less unchipped materials, to the total weight of the input materials to the chopping machine, expressed in percent determined by the following equation:

$$CE = (Wi-Wc)/Wi \times 100 \quad (13)$$

Where: CE= Chipping Efficiency, %
Wc=Weight of crushed chips in the sample, g
Wi= Weight of chipped sample, g

The chopping efficiency of the machine, as shown in Table 3, decreases with the increase of the shaft speed. It was observed that at 573rpm shaft speed, the shredding efficiency was 97.72%, and it decreased to 94.87% and 94.55%, respectively, at 1146 and 1720rpm. The analysis of variance revealed that chopping efficiency was also significantly affected by the shaft speed. The comparison among means shown in Table 3 indicated that the chopping efficiency at the lowest shaft speed of 573rpm was significantly higher than at 1146 and 1720rpm. However, when the 1146 and 1720rpm were compared, no significant differences were revealed.

Based on the sampling conducted, at 1720rpm, the most amount of crushed chips sticks to the cover of the chopping chamber, preventing them from being collected and recorded as retained or lost, which greatly affects the chopping efficiency of the device. It was observed that the faster RPM causes a greater amount of crushed chips due to the mechanical properties of banana pulp being easily damaged. However, a faster RPM of shafts means a faster cutting rate of the blades and faster feeding rate of banana pulp to the machine, resulting in a higher capacity.

Table 3: Mean chopping efficiency at various main shaft speed, %

Treatment RPM	**Means**
573	97.72 a
1146	94.87 b
1720	94.55 b

**Means with the same letter are not significantly different.*

Energy Demand

The amount of electricity consumed by the machine to chop a kilogram of banana pulp expressed in kilowatt-hour per kilogram.

$$Ed = (Pi \times T)/Wi \quad (3)$$

Where: Ed= Energy Demand, kW-hr
Pi= Power Input, (Kw)
T= operating Time, (hr)
Wi= Weight of Input Material, Kg

Figure 12 demonstrates the energy demand of the machine during the chopping process of banana and calamansi peel and rag. It was observed that chopping the calamansi rag requires a greater amount of energy due to its higher mechanical properties compared to the banana pulp. This results in higher electrical consumption and, consequently, higher costs.

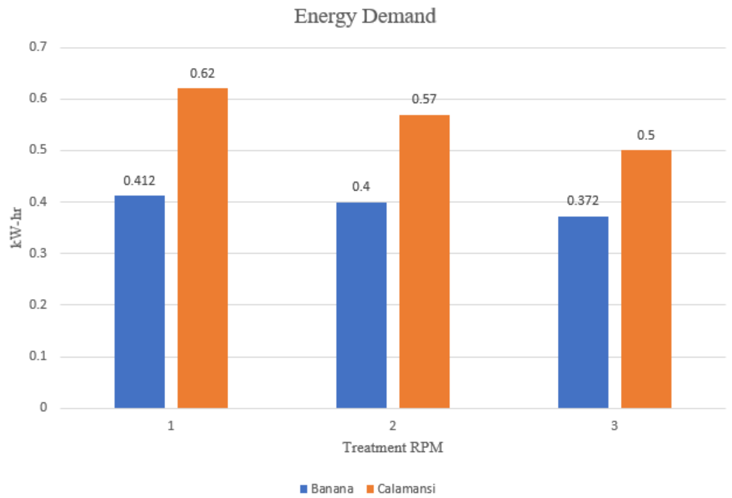

Figure 12: Energy demand of the machine.

Cost Analysis of Using the Machine

Table 4 provides a summary of the cost analysis for using the chopper, and Figure 13 presents the cost curve of using the machine. The initial cost of the machine was 115,000 Php, with an assumed life span of five years. The calculation was based on a chopping capacity of 105.54 kg/hr and a custom rate of Php 2.00/kg. The chopper's salvage value was assumed to be 10% of the initial investment of the machine.

Table 4: Cost analysis of using the machine

Particular	Amount	Unit
Annual Fixed Cost		
Depreciation Cost	20,700.00	Php/yr
Interest on Investment	3,162.50	Php/yr
Tax and Insurance	2,300.00	Php/yr
Annual Variable Cost		
Electrical Cost	8,898.24	Php/yr
Repair & Maintenance	5,750.00	Php/yr
Operator's Wage	83,200.00	Php/yr
Break-even Point	16,832.67	Kg/yr
Net Income	260,154.86	Php/yr
Rate of Return	209.78	%
Payback Period	0.4	yr

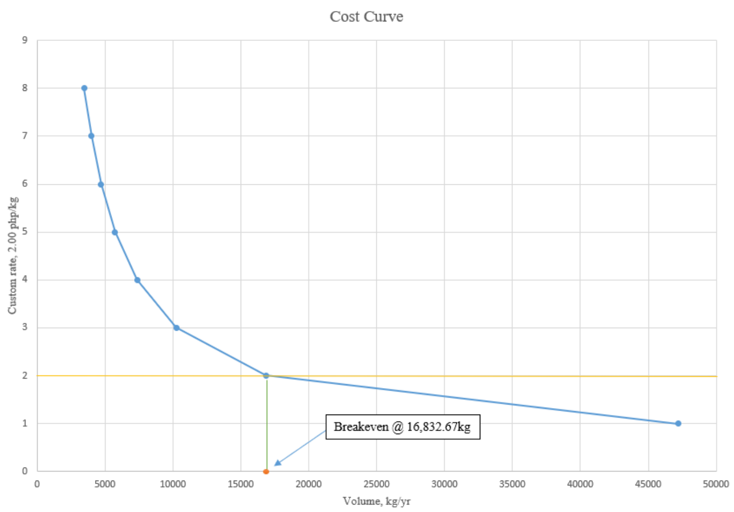

Figure 13: Cost Curve of using the machine.

CONCLUSIONS

Based on the study's objectives and findings, several conclusions have been drawn. The developed chopping machine has proven to be effective in reducing labor, processing time, and expenses for both banana chips production and the utilization of calamansi waste, thereby generating additional income for processors. Notably, the machine can be fabricated using locally available materials and local manufacturing technologies, making it accessible to the industry.

The machine's performance parameters, including chopping capacity and efficiency, have shown satisfactory results. It was observed that chopping efficiency decreases with an increase in shaft speed, but this higher speed also leads to a higher shredding capacity of the machine. At a shaft speed of 1720rpm, the energy demand of the chopper is measured at 0.372kW-hr/kg for banana pulp and 0.5kW-hr/kg for Calamansi Peel and rag.

In terms of power consumption, the machine's annual cost is deemed economical, amounting to Php 8,898.24. Additionally, the cost analysis demonstrates the machine's financial viability, with an annual operating cost of 124,010.74 Php and an initial investment cost of 115,000.00 Php. The machine is projected to benefit banana processors with a net income of 260,154.86 Php per year.

Regarding the dryer, it needs to process a total of 16,832.67 Kg/yr to reach the break-even point. The dryer shows a promising rate of return of 209.78% and a relatively short payback period of 0.4 years or 104 working days, making it a favorable investment for processors. Overall, the study suggests that the developed chopping machine and dryer have significant potential to enhance productivity, reduce costs, and boost income in the banana processing industry.

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