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Aljon E. Bocobo
Deparment of Agricultural and Biosystems Engineering, College of Engineering and Geosciences, Caraga State University

Rey B. Padios Jr
Deparment of Agricultural and Biosystems Engineering, College of Engineering and Geosciences, Caraga State University

Joe Ann L. Gaballo
Deparment of Agricultural and Biosystems Engineering, College of Engineering and Geosciences, Caraga State University

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Aljon E. Bocobo[1,2], Rey B. Padios Jr[1], Joe Ann L. Gaballo[1]
[1]Deparment of Agricultural and Biosystems Engineering, College of Engineering and Geosciences, Caraga State University, Butuan City 8600, Philippines
[2]Center for Resource Assessment, Analytics and Emerging Technologies (CReATe), Caraga State University, Ampayon, Butuan City 8600, Philippines
Corresponding author email: aljunwarriorb@gmail.com

Abstract: *This research study seeks to design, develop, and fabricate a hand-operated cacao-pod splitting device specifically for the opening process to evaluate the machine's performance in terms of machine capacity, efficiency, quality, and financial performance. Three different sizes with three replications each were evaluated. In calculating the machine performance capacity, the average time of each sample and the pod size was recorded, and the capacity was identified. Findings show that the average output capacity and efficiency of the hand-operated cacao-pod opener is about 761.09 fruit/hour and 93.33%, respectively. The machine was financially feasible, having an NPV of Php 113,844.48, an IRR of 132.702% BCR of about 2.09, and a PBP of less than a year of operation.*

Keywords: Cacao bean, Cacao pod, Pod opener.

1. INTRODUCTION

Cocoa (*Theobroma cacao L.*) is an important plantation crop in the world, belongs to Malvaceae family. Theobroma cacao, sometimes known as the cacao tree, is a well-known tree that may be found in many locations across the world. This tree produces cocoa beans, which are used to make chocolate, cocoa butter, cocoa powder, flavorings, and other products. In addition, the husk can be hydrolyzed to produce fermented sugar, and the shell can be used to make particle boards high in potassium, biogas, and potash fertilizer [1]. The high fat content of cocoa beans is well known, and they are also known to contain 300 different chemicals and antioxidants. These chemicals are advantageous in the fight against free radicals brought on by bad lifestyle choices and environmental variables [2].

According to the Cidami Organization, there is a rising demand for cocoa-related goods on the international market. This is clear from the fact that since 1970, the demand for cocoa has tripled globally. The "Cacao Double-up Program" has been proposed by the Philippines in response to this tendency [3]. The demand for cocoa beans has increased globally over time. Due to the rising global demand for chocolate and products with chocolate flavors during the past few decades. Currently, cocoa trees are grown in more than 40 different countries across an estimated 6.9 million hectares, yielding an annual output of more than 4.2 million metric tons of dried beans. The method of processing cocoa involves several phases, including the breaking of cocoa pods, extraction, fermentation, drying, dehulling, and winnowing of the beans [4]. Cocoa pods are now broken manually and inelegantly using a blade and a piece of wood. Apart from the significant amount of labor required and the length of time required for the operation, this is a difficult task. The blade causes damage to the beans, which raises losses and lowers profit. The physically demanding work results in frequent weakness and illness in the laborers and farmers, which lowers their level of health [5]. Additionally, the time needed for this manual task varies and is dependent on crop aspects such as variety as well as the attitude of the employees and their supervision [6].

Thus, this study was conducted to design and develop a cacao pod splitting device, specifically aimed to:

a. Evaluate the performance of the designed device in terms of machine capacity, cutting efficiency and its size effects;
b. Compare the capacity of the developed technology vs the traditional cacao pod splitting;
c. Determine the economic viability of the device

2. MATERIALS AND METHODS

The study used a systematic method to design and develop a hand-operated cacao-pod splitting device intended for village-level operation as well as to assess the technology's efficiency in operation, method capacity comparison, and economic viability of developed technology.

2.1 Methodological Framework

The research framework covers machine design, fabrication, and performance evaluation, as shown in Figure 1. The first step is machine designing; it starts by conceptualizing how the machine will work and what materials to use. It is followed then by machine fabrication; the researchers considered the location for fabrication to be near and accessible. It is located at the Tinshop (Torralba) building at Langihan Road, Butuan City 8600, Philippines. The researchers assist the assigned machine technician during the fabrication and decisions on the material processing, such as cutting angle bars and plane sheets, forming the blade, and assembling the machine. After the fabrication of the machine, a pre-evaluation of the machine was conducted. The researchers first tested the machine operation by opening cacao pods to check for any working problems. After the pre-evaluation, is followed by the performance evaluation following an experimental design, and then the economic analysis to test the financial performance of the developed machine.

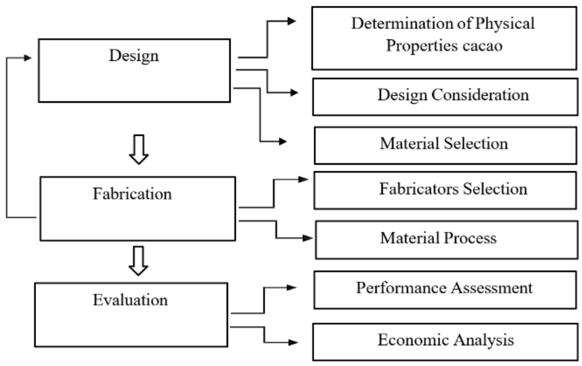


Fig. 1. The general framework of the study

2.2 Design

The hand-operated cacao pod opener was developed instead of using the traditional method. The machine consists of a handle that pushes downward to guide the holder, a buffer spring that regulates movement and keeps the mechanism stable, a holder that holds the cacao and prevents it from moving, and a cover that reduces the cacao's ability to rotate. The stainless-steel blade of the cacao pod opener is made to split the pod exactly along its natural ridge. The blade is attached to a lever mechanism that evenly presses on the pod, ensuring that it opens smoothly in both directions without damaging the bean, a sturdy table frame is its main structural component, and a pedal opener that may be operated with the foot when it is pressed, the blade mechanism is activated. This pedal system allows for hands-free operation, enhancing control and reducing the need for manual force. The frame bracket is an additional support component designed to prevent the machine from tumbling or shifting during operation.

2.2.1 Analysis of physical properties of cacao

To determine the appropriate sizes of the machine components, the researchers evaluated the physical properties of cacao pods, including length, breadth, and eccentricity, to get the design specifications for a cacao hopper, holder, and blade. Considering cocoa pods as prolate spheroid/ elliptical, 15 whole ripe cocoa pods were selected from the sample lot, and for each fruit, breadth (diameter at minor axis) was measured using a digital vernier caliper. The length of the pod was measured along its longitudinal axis (diameter at major axis) using a tape measure in millimeters. The pods were classified, based on the mid diameter, as large size (150 mm above), medium (120 mm-150 mm), and small (120mm below) categories, and the eccentricity was also considered in the study. For ergonomics and user comfort, machine dimension was considered to be 163.22 cm, the average height of Filipinos to ensure ease of operation. Weight was also considered to ensure the machine was lightweight enough for portability. Handle and pedal placement for comfortable use, reducing physical strain and allowing for natural movement.

$$e=(b-a)/b \qquad [1]$$

Where: e=eccentricity;b=major axis; a=minor axis

2.2.2 Design consideration

Some parameters was established in the fabrication of hand-operated cacao-pod splitting device, including the machine's overall dimensions, weight, and height as well as the sizes of the blade, cacao holder, and cacao cover. The design parameters of the cacao pod opening machine were established by the data gathered by the researchers to guarantee both efficiency and ease of use. To assess the physical characteristics of cacao using the W10, UF18, and BR25 varieties. As a result, the UF18 type of cacao pods had an average maximum major diameter of 18 cm, with some pods measuring up to 20 cm. The blade length was fixed at 20 cm to handle the largest pods and ensure a safe operating margin. In addition, the greatest major diameter and average minor diameter of the pods were used to determine the dimensions of the cover and holder, which came out to be 20 cm by 10 cm. The average height of a Filipino is 1.56 meters [7].

2.2.3 Detailed design

The detailed design of a hand-operated cacao pod opener features a strong, comfortable frame, sharp safe blades, a secure holder for the pod, easy-to-use handles, simple assembly, clear instructions, and safety standards.

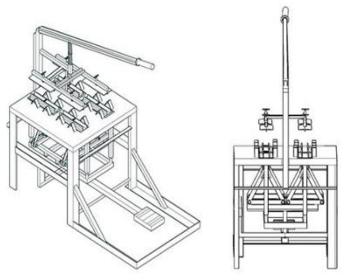


Fig. 2. Front and back view

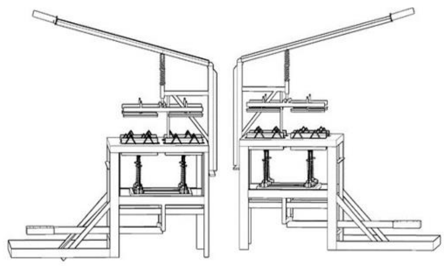


Fig. 3. Display of the right and left view

2.2.4 Material selection

The selection of materials was carefully done through canvassing and searching online. The chosen materials were: for the construction of the hand-operated cacao pod opener. The material in the fabrication of the cacao pod opener is shown in Table 1 the descriptions and functions of its materials.

Table 1. Description and Function of Materials

Materials	Description and Function
Bolts and Nuts	These are used in fixing and fastening materials together. The pair moves with a greater force when either of the two is turned [8].
Angle Bar	This structural steel bar, which has an L-shaped cross-section, supports the machine and acts as its backbone [9].

Flat Bar	This has many uses mainly as a frame, support, bases, or trims, and may vary based on its metallic composition and purposes [10].
Plain Bar	A reinforcement bar that is primarily utilized to support and structure a traction frame. Machines utilize plain sheet metal [11].
Plain Sheet	The metal sheet is used in machine bodies, automobile and truck bodies, medical tables, and or roofing [12].
Round Bar	Round bars are pre-finished and thick metal products with a circular cross-section. People call these metal bars different names. Some call them the bar stock, but others call these bars the circular rebar [13].
Metal Primer	Protects metals from exposure that would eventually lead to rust and decay of the metal and is always recommended to be used [14].
Stainless 304 Plain Sheet	Stainless steel 304 sheets are the most widely used and versatile type of austenitic stainless steel. Due to this, they make excellent materials for many kinds of uses, such as heat exchangers, lab equipment tanks, and tanks for storage in food processing facilities [15].

2.3 Fabrication and material selection process
The location for machine fabrication is located at the Tinshop (Torralba) building at Langihan Road, Butuan City 8600, Philippines. The researchers assisted the assigned technician during the fabrication and made decisions during necessary adjustments during the fabrication and significant material selection processes during fabrication.

2.4. Evaluation
In this experiment, the performance of the machine was evaluated in terms of machine performance capacity and the cutting efficiency will also be evaluated to determine the percentage of losses in cutting section operation.

2.4.1 Performance assessment
After the development of the device, it was tested for its workability and conducted a dry run of the device without loading any cacao pods to check for any mechanical issues or abnormal noises. The performance test observation guides are obtained including operating time, cycle times, and any issues encountered during testing. Collect data on the machine's performance metrics, including uptime, downtime, cycle times, and any issues encountered during testing.

2.4.2 Sample preparation
Cacao fruits are obtained from Mabuhay, Bayugan City. The samples were prepared according to their sizes and were first determined by the control sizes.

2.4.3 Experimental set-up
There are two variables of the machine: the machine capacity and the machine efficiency of the cacao opener. The experiment that will be conducted is to determine the total operating time and determine which sizes will be suited to the performance of the machine and the method comparison of manual traditional and mechanical was determined.
An analysis of variance (ANOVA) of complete randomized design (CRD) and the treatments were replicated three times. The treatments were then compared and analyzed based on the performance evaluation consideration.

2.4.4 Data gathering
The following data are gathered in this study
1. Device Capacity
2. Device Cutting Efficiency
3. Bean Damage and Bean Loss

2.4.4.1 Operating time
The total operating time was measured from the start of loading and unloading the cacao pod in 4 different hoppers.

2.4.4.2 Device performance capacity
Three different sizes small (below 120 mm), medium (120 mm-150 mm), and large (150mm above) with three replications were evaluated. In calculating the machine performance capacity, the average time of each sample and the pod size were recorded and the capacity was calculated by this:
Where:

$$C=No/T` \quad [2]$$

Where:
C = Capacity, cacao/sec
No = Number of cacao open
T = Cycle Time, sec

2.4.4.3 Device cutting efficiency
The efficiency is the measurement of the effectiveness of the machine. The efficiency measures how effectively input energy is transformed into usable output energy or work. The percentage or fraction of the output divided by the input determines a significant portion of a machine's functionality.

$$E=Nf/Nt \times 100 \quad [3]$$

Where:
E = Efficiency, %
Nf = Number of cacaos partially opened or failed to open;
Nt = Total number of cacaos tested

2.4.4.4 Bean loss and damage
To assess how effectively the machine separates the beans from the pods, monitoring bean loss and damage percentage is crucial. On the other hand, bean damage refers to damaged beans that cannot be recovered, whereas bean losses are beans that are not split from the pods but can still be retrieved. Since a machine's efficiency can never be higher than 100%, losses might be seen as a normal element of how the machine works.

Using the equation, bean damage and loss percentage (%) will be determined.

$$BD = Nb/Tm \times 100 \quad [4]$$

Where:
BD = Bean damage percentage, %
Nb = Number of beans damaged
Tm = Total number of beans.

$$BL = Ub \times 100 \quad [5]$$

Where:
BL = Bean loss percentage, %
Ub = Mass of un-cut beans

2.4.5 Statistical analysis

The data analysis used in the study was an analysis of variance (ANOVA) of complete randomized design (CRD) and T-test for unpaired samples and the treatments were replicated three times. The treatments were then compared and analyzed based on the performance evaluation consideration. The parameters computed for the Analysis were:

1. Effects of sizes on the machine's performance
2. Machine Capacity Comparison

2.5 Economic analysis

Financial analysis will be used to evaluate the new machine's financial impact. From an investor's perspective, the financial analysis demonstrates how profitable using the machine is. Using the indicators given below, one can calculate the technology's financial and economic impact.

2.5.1 Net present value

A product's Net Present Value (NPV) is calculated from the present value of the net cash flows. If the NPV is positive, it is profitable at a given interest rate. Expressed mathematically by.

$$NPV = \sum_{n=0}^{N} \frac{Cn}{(1+r)^{n}} \quad GFGFHGHG\ [6]$$

Where:
N = the Total number of periods
n = non-negative integers
Cn = the cash flow
r = internal rate of return

2.5.2 Internal rate of return

The Internal Rate of Return (IRR) is the interest rate at which the NPV of costs throughout the product's life span equals the NPV of benefits. The product is said to be profitable if the IRR is positive. The equation expresses:

$$0 = NPV = \sum_{t=0}^{T} \frac{C_t}{(1+IRR)^{t}} \quad \mathbf{GFHGHGG}[7]$$

2.5.3 Benefit-cost ratio

The Benefit – Cost Ratio (BCR) is a method for calculating the project's net benefits concerning the net cost. If the BCR is greater than 1, then it means that the product can provide investors with a positive net present value. It is expressed using the equation.

BCR= (PV of benefit expected from the product)/ (cost of the product) [8]

2.5.4 Payback period

The payback Period (PBP) is when a project's total cash flow becomes positive. It determines how fast the investor can recover the investment. It is expressed using the equation.

PBP= (Initial Cost)/(Annual Cash Inflows) [9]

3. RESULTS AND DISCUSSION

The four sections of the results and discussion comprise the machine's design, performance evaluation, machine performance capacity comparison with manual methods, and machine financial feasibility

3.1 Cacao pod splitting device

A cocoa pod splitting device is a simple machine made of standard readily available components. Simple in design, it is an easy-to-use machine for breaking cocoa pods of all sizes figure 6 shows the actual prototype of a hand-operated cacao-pod opener. The net weight of the machine was 45 kilograms, the cover was intended to stop cacao from moving, sizes with the length and width of the cacao were measured at 20 cm and 9 cm respectively. The holder is 10 cm in length it consists of two triangular shapes positioned with a 4 cm distance between them primarily to prevent cacao pods from rolling during processing. The blade located 10 cm below the cacao cover serves as the mechanism for opening the cacao pods. The 93-cm-long bar handle includes a spring beneath it that can be adjusted up or down to control the appropriate force used to hold the cacao covering in place. The dimensions and components of the hand-operated cacao pod opener are 55 cm by 55 cm by 60 cm corresponding to the average height of the operator while standing [7] and the machine's overall height from the holder to the ground is 106 cm.

Fig. 4. Cacao-Pod Splitting Device Prototype

3.2 Performance evaluation

The machine's performance was conducted in this experiment, including evaluations of the machine's capacity, efficiency, and quality and using of Analysis of Variance (ANOVA) in a Completely Randomized Design (CRD). The t-test of unpaired samples, which was also used to compare machine performance, allowed us to see the differences between each machine's capacity and efficiency. This assisted in determining where improvements could be made and which machines were more suitable for specific jobs.

3.2.1 Operating time

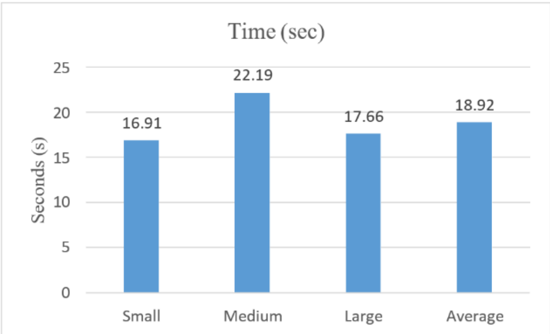
Through an evaluation of the total operating time for four different hoppers of cacao pods, the total operational time which is the amount of time from the loading, operating, and unloading of cacao was calculated. Besides BR25 variety was used and the evaluation also included three pod size categories: small (below 12 cm), medium (12–15 cm), and large (above 15 cm). Table 6 shows the average number of fruits observed per second for each size category. These findings are significant in the efficiency of fruit observation.

Table 2. Total operating time on different sizes

	Time (secs)		
	Loading/Operating	Unloading	Total operating time
Small	9.02	7.89	16.91
Medium	9.89	12.3	22.19
Large	11.06	6.6	17.66

Figure 5 displays the total operating time data, revealing that the average operation time was 25.1 seconds during the observation period. Medium-sized objects had longer operating times compared to smaller sizes. It was observed that small-sized pods had significantly faster operation times compared to medium and large pods, indicating the machine's enhanced efficiency and suitability for smaller pod sizes.

Fig. 5. Graphical representation of total operating time



3.2.2 Machine capacity

In this study, the researchers evaluated the effect of the size of the commodity on the time taken, expressed in seconds. The researchers were given a specific job to complete using three different treatments small (below 12 cm), medium (12 cm-15 cm), and large (15cm above), and their completion times were recorded.medium-sized and the least capacity observed by cutting large-sized cacao.

Table 3 presents the machine's capacity in terms of how many fruits it can process per hour. For small-sized fruits, the machine can process around 851.57 fruits per hour on average. For medium-sized fruits, it can handle approximately 648.94 fruits per hour on average. For large-sized fruits, the capacity is roughly 815.4 fruits per hour on the total average is 761.09 fruit/hour.

Table 3. Machine capacity in fruit/hour

Treatment	n *	BD±SD**
Small	3	14.1±2.40^{ab}
Medium	3	11.46±0.08^{ab}
Large	3	13.49±1.22^{ab}

3.2.3 Machine efficiency

Table 4 shows the different observations of the machine's cutting efficiency concerning the commodity sizes. The results are obtained by dividing the fruit that is opened with the difference of partially or failed to open over the total number of cacao fruits. The operation was performed on the various samples in three trials. As observed, there's a slight difference in the percentage of fruit output across different. It is because the blade size is suitable for small cacao sizes, it could lead to better contact and more efficient cutting or opening of the cacao pods.

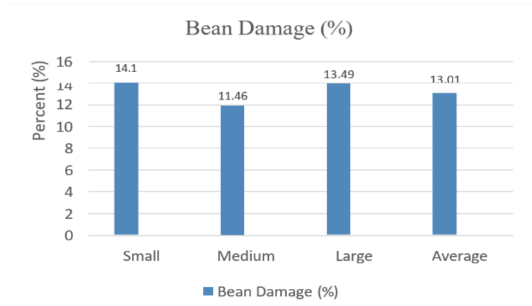
Table 4. Machine Efficiency

	Observation (%)
Small	96.67
Medium	93.33
Large	90
Average	93.33

3.2.4 Bean damage

Figure 9 represents the graphical representation of bean damage percentage on different trials carried out by size. As observed in the given data small sizes have the highest value of bean damage it is because the vertical clearance of the cover is just suitable for small-sized cacao pods. Additionally, to pod properties, the presence of pod diseases further exacerbates bean damage. Block pod diseases cause beans to remain attached to the pod even after opening, increasing the likelihood of damage during processing. The mechanical force exerted during pod opening can crush or break these attached beans, contributing to overall bean damage.

Fig. 6. Graphical representation of bean damage



3.2.5 Influence of cacao size on bean damage

The data in Table 5 appears to represent an experiment assessing the effect of different treatments (potentially related to the size of cacao pods) on bean damage for treatment 1 the mean bean damage of 14.1 with a standard deviation of 2.40, for treatment 2 mean bean damage of 11.46 with a standard deviation of 0.08, treatment 3 mean bean damage of 13.49 with a standard deviation of 1.22. The lowercase letters (a, b) denote the statistical significance between the treatments. In this case, treatments with different letters indicate that there are statistically significant differences ($P < 0.05$) based on the Least Significant Difference (LSD) Test. The results show in Table 9 that treatments 1, 2, and 3 share the same letter 'a', indicating that there is no statistically significant difference in bean damage between these treatments. That means several factors might influence the result.

Table 5. Influence of cacao size on bean damage

**n- number of samples; ** ± SD- standard deviation. **Different small letters within the same column indicate statistical difference (P<0.05) using the Least Significant Different (LSD) Test*

3.2.6 Bean loss

Table 6 illustrates the percentage representation of bean losses during operation on different sizes. The bean loss percentage was obtained by the number of bean loss divided by the total number of beans and multiplied by 100. As observed in the table, size large has the maximum percentage of bean loss among the 3 treatments. The reason for this is that it can be related to the physical traits of large-sized as well as medium-sized cacao pods, including tending to have hollow interiors. Due to their bigger size, these pods are more likely to contain spaces or empty areas, which increases the risk that the beans will come loose and fall to the ground during operation.

Table 6. Tabular representation of bean loss

Bean Loss (%)	
Small	16.66
Medium	16.66
Large	15.87
Average	16.40

3.3 Pperformance capacity comparison

This evaluation emphasizes machine efficiency in a particular sitting. To get the comparison method capacity of the machine, it will be compared to the traditional manual method [3]. As observed, in Figure 30 comparing the averages, the mechanical method demonstrates significantly higher production yield (761 fruits per hour) compared to the manual method (660 fruits per hour). This suggests that the mechanical method has a substantial impact on increasing production yield, as evidenced by the notably higher output of 20% compared to the manual traditional as observed across multiple observations. Therefore, it can be inferred that adopting the mechanical method can lead to a significant improvement in production efficiency and yield compared to the traditional manual approach.

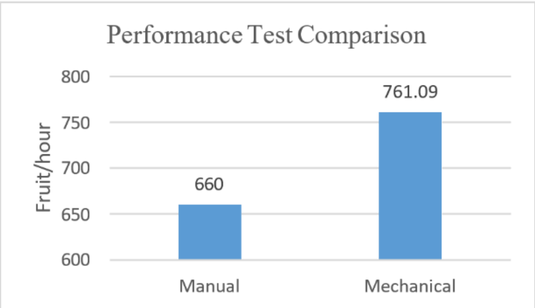


Fig. 7. Graphical representation of performance test

The average value for the Mechanical process (761.09) is higher than the average value for the Manual process (660). This suggests that the mechanical process might be more efficient or produce a better outcome compared to the Manual process. The variances are 14400 for manual and 11679.4 for mechanical, indicating the spread or variability of the data points around the mean for each process. Even though the variances are not equal, they are relatively close, suggesting that the variability in both processes is somewhat similar. The p-value is 0.029. This is less than the significance level of 0.05 (5%), which indicates that there is a statistically significant difference between the manual and mechanical processes. At a 5% significance level, the difference in means between the manual and mechanical processes are statistically significant. This means that the Mechanical process performs significantly differently from the Manual process.

Table 7. T-test of Significant Difference between the Two Methods

	Manual	Mechanical
	660	761.09
Variance	14400	11679.4
P-value		0.029
Interpretation	*Significance @5 level	

The analysis shows that the mechanical process has a significantly higher mean compared to the manual process, indicating that it is more effective at the 5% significance level. This suggests that switching to or implementing the Mechanical process could yield better results, assuming other practical factors are also favorable.

3.4 Economic analysis of the machine

The machine's financial impact was evaluated using financial analysis. The machine's liquidity, profitability, and overall financial condition are determined through financial analysis. To determine the machine's economic feasibility, it involves assessing its previous, present, and possible future performance. The machine's potential risks and opportunities can also be found with the help of financial analysis. The following list of indicators provides further explanation of how the machine's financial and economic impact was determined. The financial analysis was assumed to be the farmer’s perspective. The machine was developed with a three-year lifespan in consideration, along with the assumptions provided. As indicated, the computation results reveal that the designed cacao pod opener was economically feasible. For a developed machine, the benefit-cost ratio value of 2.09 is acceptable, since it exceeds the required value of 2. The newly invented cacao pod opener may produce a relatively high net present value (NPV) of revenue under constant price and production cost assumptions. Its value is Php 113,844.48 at a 10% discount rate.

4. CONCLUSION

The hand-operated cacao pod splitting device is capable of splitting the cacao pod. It produces an efficient cutting result and cutting performance. From the results, smaller pods have a greater average fruit capacity rate per hour compared to their medium- and larger-sized. This information shows the importance of using small-sized cacao pods to achieve the highest level of cutting efficiency. In evaluation of bean losses size large has the highest percentage of bean loss among the 3 sizes. The reason for this is that it can be related to the physical traits of large-sized cacao pods, including tending to have hollow interiors. Due to their bigger size, these pods are more likely to contain spaces or empty areas, which increases the risk that the beans will come loose and fall to the ground during operation. In the evaluation of bean damage large size has the highest percentage of bean damage followed by medium size. This is because according to the assessment, there is a noticeable difference in the percentage of damaged beans between small, medium, and large cacao sizes. This result is caused by the blade's clearance height between the holders, which the researcher considers is more suitable for cacao pods that are smaller in size.

Meanwhile, the comparison of results in performance capacity in crushing cacao pods was obtained from the two methods, manual and mechanical. Based on the results, a mechanical method has a higher capacity for crushing cacao pods than the manual method with an average of 761.09 fruits per hour using the cacao pod crushing machine compared to 660 fruits per hour of traditional manual pod splitting.On the other-hand, machine was financially feasible, having an NPV of Php 113,844.48, an IRR of 132.702% BCR of about 2.09, and a PBP of less than a year of operation.

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