Response Surface Optimization of Mechanical Extractor of Pith from Sago (Metroxylon sagu) Logs

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Abstract: *This study aimed to optimize the mechanical extraction of sago pith from Metroxylon sagu using Response Surface Methodology (RSM) and a Randomized Complete Block Design (RCBD). It examined the effects of teeth configuration, log length, and rasper speed on key performance indicators: extraction rate, energy use, capacity, efficiency, fineness modulus, and energy consumption. Trials showed that teeth notably impacted machine efficiency and output quality. The optimal setup of 8 teeth and a 14-inch log length achieved a 1,065.07 kg/hr extraction capacity, 85.06% efficiency, a fineness modulus of 1.99, and 0.0018 kWh/kg energy use. Despite some variability due to teeth sharpness during field tests, results confirmed that optimized settings enhanced processing efficiency and product consistency. This research highlights the importance of design optimization in improving mechanized sago extraction and supports its potential for wider rural and commercial use.*

Keywords: Sago pith extraction; Response Surface Methodology; Agricultural machinery optimization; Extraction efficiency; Metroxylon sagu.

1. INTRODUCTION

The sago palm is an excellent crop for sustainable agriculture. The word ‘sago’ is originally Javanese, meaning starch-containing palm pith. The scientific name is derived from ‘metra’, meaning pith or parenchyma, and ‘xylon’ meaning xylem. It is considered as the ‘starch crop of the 21st century’ by many scientists[1].
According to [2] sago palm (*Metroxylon sagu*) has been a promising crop with its exceptionally high starch content compared to other starch-producing crops. Sago starch has diverse applications in both food and non-food industries. Sago palm originated in the area extending from the Moluccas of Indonesia to New Guinea. A tropical plant that thrives in swampy peat environments, sago palms are planted throughout Southeast Asia and Oceania. A sago palm's upright trunk is roughly 10 meters tall and 75 centimeters thick. Starch is stored in the trunk throughout its 7–15-year vegetative period. As it matures, a sizeable branching inflorescence forms at the top of the trunk. Starch reserves peak before flowering and fruiting, depleting these stores. The whole fruit that falls from the sago palm causes it to die. The epidermis, cortex, and pith, or conjunctive tissue, comprise the trunk. Vascular bundles and storing parenchyma cells are found in the pith. Amyloplasts, packed in the storage parenchyma cells, contain simple starch granules that are oval or polygonal in shape and range in size from 20 to 60 µm. Amylose makes up around 27% of sago palm starch granules. Pith is composed of 79–88% starch and sugars and 6–12% soluble substances [3].
In the Philippines, sago palm plantations are primarily found in the Visayas and Mindanao regions, with Agusan del Sur in Northeastern Mindanao having the largest production area. The province is estimated to have around 600 to 650 hectares dedicated to sago cultivation, followed by Agusan del Norte with approximately 29.75 hectares[4]. The sago palm stem, which is the source of sago starch, is internationally referred to as "rumbia" [5] and locally known in the Philippines as "lumbia" [6].
Traditional sago starch extraction is highly labor-intensive and time-consuming, requiring extensive manual effort [7]. These challenges highlight the need for technological innovations to enhance machine performance. While the current sago pith extracting machine is considered efficient, researchers have found room for improvement to further optimize its operation.
Technological advancements in agricultural machinery, particularly through the application of statistical optimization techniques, offer promising solutions to various challenges. Response Surface Methodology (RSM) is a powerful tool for optimizing processes by evaluating the relationships between multiple independent variables and their effects on a desired response [8]. When combined with the Randomized Complete Block Design (RCBD), which minimizes variability by blocking similar experimental units together, RSM further refines the optimization process by analyzing interactions between variables and identifying optimal conditions [8]. This integrated approach enhances the efficiency and sustainability of operations,

making it invaluable for improving the performance of agricultural machinery like the sago pith extracting machine.

This study aimed to utilize Response Surface Methodology (RSM) in the optimization of the mechanical pith extractor for sago logs. Specifically, it aimed to:

1. Evaluate the impact of factors of different existing teeth configurations, rasper rotational speed, and log lengths on machine performance. The evaluation will focus on the following performance indicators:
   a) Extraction Capacity
   b) Extraction Efficiency
   c)Fineness Modulus
   d)Energy Consumption
2. Optimize the factors using RSM and RCBD.
3. Analyze the interactions among the selected factors and assess their influence on the machine's overall performance.

Beyond performance improvements, this research contributes to strengthening the sustainability of sago production, particularly for community-based farmers and rural associations who rely on sago as a livelihood commodity. By identifying the most effective machine configurations, the study supports local economic development, job creation, and the long-term viability of sago cultivation. As the final step prior to commercialization, the findings bridge the gap between research and industrial application, offering valuable insights for advancing future mechanized extraction technologies.

2. Materials and Methods

2.1 Methodogical Framework

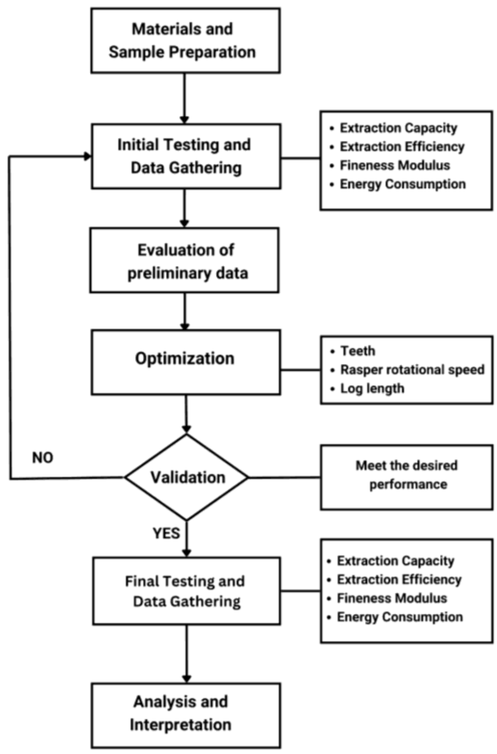

Figure 1. Methodological Framework

The study followed a structured methodological framework. Materials were prepared, and initial tests were conducted to obtain baseline values for extraction capacity, extraction efficiency, fineness modulus, and energy consumption. These results guided the optimization phase, which examined the effects of three factors—number of teeth, rasper rotational speed, and log length. Response Surface Methodology (RSM) integrated with a Randomized Complete Block Design (RCBD) was used to model factor interactions and identify optimal settings.
The optimized parameters were subjected to validation testing to confirm whether performance targets were met. When validation succeeded, final testing was conducted to ensure repeatability and consistency using the same performance indicators. The framework concluded with the analysis and interpretation of all experimental results.

2.2 Materials and Sample Preparation

The sago logs were cut to their specified lengths, as shown in Figure 1, from the sago palm farm in Trento, Agusan del Sur, totaling 18 logs. Afterward, the sago logs were processed using the sago pith extracting machine to extract the pith. After all the samples were extracted, they were weighed, and the data for other parameters were recorded.

Figure 2. Sample Preparation

2.3 Initial Testing and Data Gathering

Following preparation, initial testing and data gathering were carried out to establish a performance baseline for the machine. Key performance indicators such as:

2.3.1 Extraction Capacity

It refers to how much pith the machine can extract in each amount of time. It shows how fast the sago pith extractor performs its main task, which is to remove the pith from inside the sago log. To measure this, the total weight of the pith that has been extracted is divided by the total time the machine was in operation. This gives a clear idea of the machine's output rate, in other words, how productive the machine is over time.
A higher extraction capacity means that the machine works efficiently and can process more pith in less time. This is important, especially in large-scale or commercial operations, where faster processing can lead to better productivity and lower labor costs. The evaluation of extraction capacity is typically done using the following formula:

$$\boldsymbol{EC} = \left(\frac{\boldsymbol{W_p}}{\boldsymbol{t}}\right) \quad (1)$$

where Extraction Capacity (EC) of the machine is measured in (kg/hr.), W_p is the weight of the extracted pith in kilograms, and t is the total operating time in hours. This simple equation helps assess the performance of different machine settings or designs. By comparing extraction capacity values from various tests, researchers can determine which combination of variables (like teeth or log length) works best for efficient pith extraction.

2.3.2 Extraction efficiency

It measured how much usable pith was successfully removed from the sago trunk compared to the total amount of pith available in the sample. It showed how well the machine performed its task, not just at speed, but in how little material was wasted during the process. In simple terms, it reflected how completely and effectively the machine extracted the pith from the trunk.

This efficiency was important because a good machine should recover as much pith as possible in the shortest time while leaving very little behind. A high extraction efficiency meant that the machine worked both quickly and thoroughly. The evaluation was done using the following formula:

$$\boldsymbol{Eeff}\ (\%) = \left(\frac{W_p}{P}\right) \times \mathbf{100} \qquad (2)$$

where P is the potential weight of the pith inside the log (kg), which can be determined by adding the weight of the rasped pith (kg), the weight of scattering loss (kg), and the weight of the un-rasped pith (kg).

2.3.3 Fineness Modulus

It was used to indicate how fine or coarse the rasped pith particles were. It was calculated by adding up the cumulative percentages of pith retained on a set of standard sieves and dividing the total by 100. A higher value meant coarser particles, while a lower value indicated finer material. This measurement helped assess the quality of the rasping process, which can affect further processing or product quality.

$$\boldsymbol{FM} = \left(\frac{\boldsymbol{CPWR}}{\mathbf{100}}\right) \qquad (3)$$

where CPWR represented the total percentage of material retained on each sieve, added together. The fineness modulus was then obtained by dividing this total by 100. This value gave a quick indication of the overall particle size distribution, with a higher FM indicating coarser pith and a lower FM indicating finer particles.

2.3.4 Energy Consumption

It is the amount of electrical energy used by the sago pith extractor during its operation. It indicated how much power the machine required to carry out the rasping or extraction process over a certain period. This parameter was important for evaluating the machine's efficiency, particularly in terms of operating costs and energy usage. In the study, energy consumption was measured to determine how efficiently the machine used power relative to the amount of pith it extracted. Ideally, lower energy consumption with higher output was preferred, as it meant the machine could perform more work while using less electricity. This was especially beneficial for long-term or large-scale applications.

Energy consumption was calculated using the formula:

$$\boldsymbol{EC}\ (\boldsymbol{kWh}) = \frac{\boldsymbol{P} \times \boldsymbol{t}(\boldsymbol{hrs})}{\mathbf{1000}} \qquad (4)$$

By analyzing energy consumption along with other performance indicators such as extraction capacity and efficiency, the overall practicality and effectiveness of the sago pith extractor were better understood.

2.4 Analysis and Interpretation

The final step involved analyzing and interpreting all gathered data to evaluate the impact of the optimized parameters. The comparison of initial and results allowed for the identification of notable improvements and ensured that the sago pith extractor operated at its most efficient settings, contributing to a more effective and energy-saving extraction process.

3. Results and Discussion

This chapter presents the results of the experimental trials and the analysis conducted to optimize the performance of the mechanical sago pith extractor. The study employed a Randomized Complete Block Design (RCBD) to account for variability among experimental units and ensure more reliable and accurate results. Response Surface Methodology (RSM) was then applied to evaluate the effects of key operational parameters, such as rasper rotational speed, log length, and number of teeth, on performance indicators, including extraction capacity, efficiency, fineness modulus, and energy consumption. This statistical approach allowed for the identification of significant factor interactions and the determination of optimal machine settings. The findings were discussed in relation to theoretical expectations and their practical implications for improving sago processing efficiency.

3.1 Extraction Capacity

Extraction capacity was determined by dividing the total weight of extracted sago pith by the total operating time of the machine. The extraction capacity was analyzed using a linear model, with blade teeth (Factor A) and log length (Factor B) as independent variables. The ANOVA results in Table 1 demonstrated that the overall model was statistically significant ($F = 31.48$, $p < 0.0001$), indicating a strong relationship between the response and the predictor variables.

Among the factors tested, blade teeth (A) emerged as the only significant term ($p < 0.0001$), contributing meaningfully to the model. In contrast, log length (B) was found to be statistically insignificant ($p = 0.5729$), suggesting minimal influence on extraction capacity within the tested range.

Table 1. ANOVA for a linear equation for the extraction capacity

Source	Sum of Squares	df	Mean Square	F-value	P-value	
Block	4257.68	2	2128.84			
Model	1.53E+06	2	7.66E+05	31.48	<0.0001	significant
A-Blade teeth	1.52E+06	1	1.52E+06	62.62	<0.0001	
B-Log Length	8137.85	1	8137.85	0.3345	0.5729	
Residual	3.16E+05	13	24330.43			
Cor Total	1.85E+06	17				

Model performance metrics further support its adequacy. The model exhibited a coefficient of determination (R^2) of 0.8288, with an adjusted R^2 of 0.8025, and a predicted R^2 of 0.6662, shown in Tables 2 and 3. These values reflect a reasonably strong fit, with only minor discrepancies between observed and predicted values. Additionally, the Adeq Precision value of 8.125 exceeds the threshold of 4, confirming a satisfactory signal-to-noise ratio and model reliability for navigation of the design space.

The regression equation in coded form is:

Extraction Capacity = 799.71 - 290.93*A + 25.57*B
Where:
A = Teeth (number of teeth)
B = Log Length (inches)

This indicates that an increase in the number of teeth leads to a reduction in extraction capacity, while longer logs have a slight positive influence.

Table 2. Fit results for extraction capacity

Source	Sequential p-value	Lack of Fit p-value	Adjusted R^2	Predicted R^2	
Linear	<0.0001		0.8025	0.6662	Suggested
2FI	0.2975		0.8053	0.6365	
Quadratic	0.239		0.8138	0.6249	Aliased

Table 3. Fit statistics for extraction capacity

Std. Dev.	155.98	R^2	0.8288
Mean	796.87	Adjusted R^2	0.8025
C.V. %	19.57	Predicted R^2	0.6662
		Adeq Precision	8.1245

The 3D surface in Figure 2, the plot supports this interpretation, showing a declining trend in extraction capacity with increasing blade teeth, regardless of log length. Maximum extraction was observed at lower blade tooth counts and higher log lengths, consistent with the coded model equation.

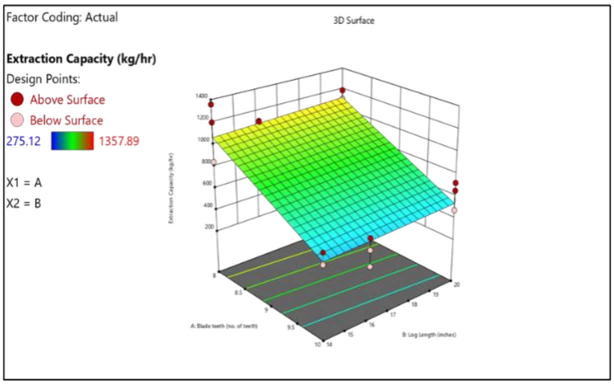

Figure 2. Extraction Capacity 3D surface plot

3.2 Extraction Efficiency

The 3D surface plot for extraction efficiency, shown in Figure 3, demonstrates how the number of teeth (Factor A) and log length (Factor B) influence the efficiency of the extraction process. The values range from 47.25% to 89.14%, with higher efficiency predominantly occurring at higher blade teeth counts and shorter log lengths. The surface shows a downward trend in efficiency as log length increases, while blade teeth have a stronger impact, indicating a steeper slope in that direction.

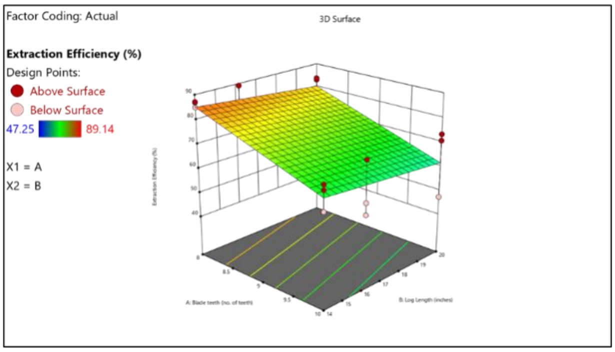

Figure 3. Extraction Efficiency 3D surface plot

As can be gleared from Table 4 below, the corresponding ANOVA table reveals that the model is statistically significant with an F-value of 14.14 and a p-value of 0.0005, indicating a very low probability that the results are due to random variation. Among the individual factors, blade teeth ($p = 0.0002$) were found to significantly affect extraction efficiency, while log length ($p = 0.2741$) was not statistically significant at the 0.05 level.

Table 4. ANOVA table for linear equation for Extraction Efficiency

Source	Sum of Squares	df	Mean Square	F-value	P-value	
Block	198.04	2	99.02			
Model	1610.89	2	805.44	14.14	0.0005	significant
A-Blade teeth	1536.61	1	1536.61	26.97	0.0002	
B-Log Length	74.27	1	74.27	1.3	0.2741	
Residual	740.59	13	56.97			
Cor Total	2549.52	17				

Fit statistics in Table 5 below show an R^2 value of 0.6851, meaning the model explains about 68.51% of the variability in extraction efficiency. However, the Predicted R^2 (0.3819) is notably lower than the Adjusted R^2 (0.6366), suggesting a potential overfit or an issue such as block effects or model complexity. Despite this, the Adequate Precision of 7.870 exceeds the threshold of 4, confirming that the signal-to-noise ratio is sufficient for the model to be used for navigating the design space.

Table 5. Fit statistics for extraction efficiency

Std. Dev.	7.55	R^2	0.6851
Mean	73.66	Adjusted R^2	0.6366
C.V. %	10.25	Predicted R^2	0.3819
		Adeq Precision	7.8699

The final coded equation is:
Extraction Efficiency = 73.39 – 9.24*A – 2.44*B
Where:
A = Teeth (number of teeth)

B = Log Length (inches)

This equation highlights that an increase in the number of blade teeth (A) and log length (B) leads to a decrease in extraction efficiency, with the number of blade teeth showing a more pronounced effect.

3.3 Fineness Modulus

The fineness modulus was analyzed to determine the particle coarseness of the sago produced. It was calculated based on the weighted average of retained particles during sieving. The fineness modulus values ranged from 1.42 to 2.86**,** as shown in Table 6. The highest fineness modulus was observed at the treatment combination of 10 blade teeth and 20-inch log length. The surface regression analysis presented in Figure 18 demonstrates that fineness modulus can be predicted using a linear model (Eq. 16).

Fineness Modulus = 2.27 + 0.1833*A + 0.1036*B
Where:
A = Blade Teeth (number of teeth)
B = Log Length (inches)

Table 6. ANOVA for a linear equation for the fineness modulus

Source	Sum of Squares	df	Mean Square	F-value	P-value	
Block	0.3678	2	0.8139			
Model	0.7385	2	0.3692	1.81	0.203	Not significant
A-Blade teeth	0.605	1	0.605	2.96	0.109	
B-Log Length	0.1335	1	0.1335	0.6533	0.4335	
Residual	2.66	13	0.2043			
Cor Total	3.76	17				

The results from the ANOVA for the linear model, shown in Table 6, indicate that the model is not statistically significant, with a p-value of 0.2030. The individual terms for blade teeth (p = 0.1090) and log length (p = 0.4335) were also not significant at the 95% confidence level.

Table 7. Fit summary for fineness modulus

Source	Sequential p-value	Lack of Fit p-value	Adjusted R^2	Predicted R^2	
Linear	0.203		0.0971	-0.4712	Suggested
2FI	0.5254		0.0556	-0.6498	
Quadratic	0.2755		0.0799	-0.7717	Aliased

The model's overall performance was further assessed using the fit summary in Table 7. The adjusted R^2 was 0.0971, showing that the model explained only about 9.71% of the variation in fineness modulus. More critically, the predicted R^2 was negative (-0.4712), indicating that the model had poor predictive capability. Although the linear model was labeled as "Suggested" due to its lower sequential p-value compared to the 2FI and quadratic models, it still demonstrated weak explanatory and predictive power. Additionally, the quadratic model was aliased and therefore could not be evaluated.

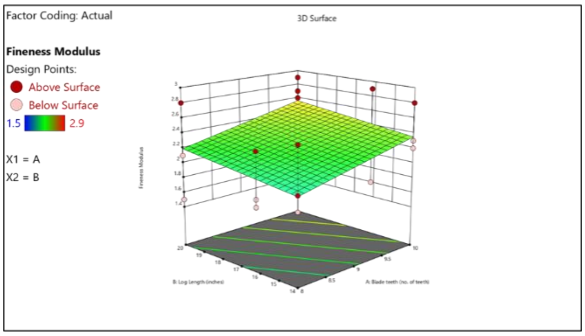

Figure 4. Fineness Modulus 3D surface plot

3.4 Energy Consumption

The energy consumption in the system, as analyzed and shown in the graph, ranged from 0.0014 to 0.004 kWh/kg, as presented in the 3D surface plot (Figure 5). In the context of energy efficiency, lower energy consumption values are more desirable, indicating a more energy-efficient operation. The most favorable energy consumption was achieved with a combination of a lesser number of teeth and longer log lengths.

A surface regression model and Analysis of Variance (ANOVA) have been done to analyze the effect of the two factors on the measured response. It was found that the energy consumption is best explained by the following linear model:
Energy Consumption = 0.0023 + 0.0007A - 0.0002B
Where:
A = Teeth (number of teeth)
B = Log Length (inches)

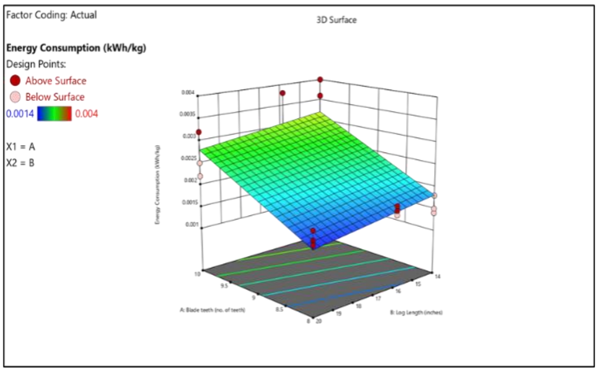

Figure 5. Energy Consumption 3D Plot

Table 8. ANOVA for the 2FI model of energy consumption

Source	Sum of Squares	df	Mean Square	F-value	P-value	
Block	2.34E-07	2	0.0001			
Model	9.19E-06	2	0.0002	15.66	0.0003	significant
A-Blade teeth	8.68E-06	1	0.0002	29.58	0.0001	
B-Log Length	5.07E-07	1	0.0001	1.73	0.2115	
Residual	3.81E-06	13	0.0001			
Cor Total	0	17				

As shown in the ANOVA results (Table 8), the model is statistically significant with a Model F-value of 15.66 and a p-value of 0.0003, indicating a low probability that the observed variation is due to noise. The Adeq Precision ratio of 7.154 suggests a sufficient signal for navigating the design space. However, the Predicted R^2 value (0.4431) is not as close to the Adjusted R^2 (0.6615) found in Table 9, implying potential issues such as block effects or the need for model refinement. Among the two factors analyzed, the number of teeth (Factor A) was found to notably influence energy consumption ($p= 0.0001$), while log length (Factor B) did not show a statistically significant effect ($p=0.2115$) shown Table 11. This suggests that optimizing the number of teeth is more critical for reducing energy use. This observation is supported by the 3D surface plot above in Figure 5, where a steeper gradient is observed along the teeth axis compared to the log length axis. Specifically, increasing the number of teeth tends to increase energy consumption, whereas changes in log length have a less pronounced and inconsistent effect.

Table 9. Fit statistics for energy consumption

Std. Dev.	0.005	R^2	0.7066
Mean	0.0023	Adjusted R^2	0.00615
C.V. %	23.27	Predicted R^2	0.4431
		Adeq Precision	7.1542

3.5 Attained Optimum Condition

Table 10. Criteria for Optimization

Response	Goal	Lower Limit	Upper Limit
Extraction Capacity	Maximize	500	1500
Extraction Efficiency	Maximize	80	100
Fineness Modulus	Minimize	1.42	2.86
Energy Consumption	Minimize	0.0014	0.004

Table 10 presents the optimization criteria for the four key responses: extraction capacity, extraction efficiency, fineness modulus, and energy consumption. Each response was assigned a specific goal—either maximization or minimization—along with defined lower and upper limits. Extraction capacity (500–1500 kg/hr) and extraction efficiency (80–100%) were set to be maximized to achieve the highest possible performance.

In contrast, energy consumption (0.0014–0.004 kWh/kg) and fineness modulus (1.42–2.86) were minimized to reduce power usage and obtain finer pith quality. These criteria guided the optimization process in identifying the most favorable combination of factors for efficient, high-capacity extraction with low energy demand and improved product quality.

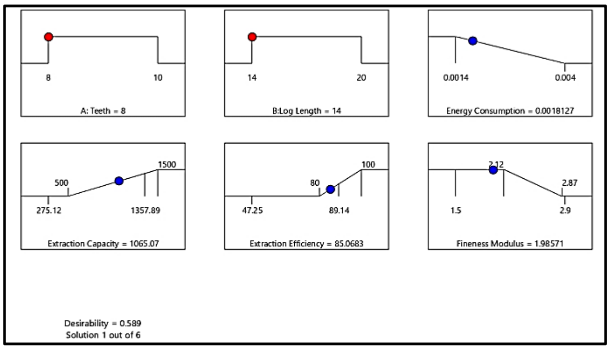

Figure 6. Optimization Result

Optimization was achieved based on the results obtained using both Randomized Complete Block Design (RCBD) and Response Surface Methodology (RSM), the optimal machine settings were determined to be a log length of 14 inches and a blade configuration with 8 teeth. Under these optimized conditions, the sago pith extractor demonstrated significantly improved performance compared to the results of [6]. The extraction capacity reached 1065.07 kg/hr, indicating a high processing rate. The extraction efficiency was recorded at 85.06%, showing that the machine was able to recover most of the available pith with minimal waste. The fineness modulus was 1.98571, suggesting a moderately fine texture of the rasped pith, which is suitable for further processing. In addition, the energy consumption was relatively low at 0.0018 kWh/kg, reflecting efficient power utilization. Overall, the use of RSM and RCBD effectively identified the best combination of variables, leading to optimal machine performance in terms of productivity, quality, and energy efficiency.

3.6 Post Analysis

Table 11. Summary result for final testing

Log length (in)	No. of blade teeth	Extraction Capacity (kg/hr)	Extraction Efficiency (%)	Fineness Modulus	Energy Consumption (kWh/kg)
14	8	409.64	71.43	1.2	0.00424
14	8	518.07	75.44	1.2	0.00225
14	8	472.34	72.55	1.2	0.00251
	AVE	**466.68**	**73.14**	**1.2**	**0.00300**

Following the experimental trials and optimization procedures, a post-analysis was conducted to evaluate the overall performance of the sago pith extracting machine under optimized conditions. The assessment focused on extraction capacity, extraction efficiency, energy consumption, and product quality, and verified consistency across multiple trials.

Using the optimal settings of a 14-inch log length and eight rasping teeth (Table 11), the machine achieved an average extraction capacity of 466.68 kg/hr, an efficiency of 73.14%, a fineness modulus of 1.2, and an energy consumption of 0.00300 kWh/kg. These results met the targets for minimizing energy consumption and fineness modulus but fell short of the expected extraction capacity and efficiency.

A likely factor behind the reduced performance was the diminished sharpness of the rasping teeth during the final tests, which affected rasping effectiveness. This underscores the need for maintaining uniform tool condition to ensure accurate comparisons and to attribute performance changes solely to machine settings rather than tool wear.

3.7 Physical Characteristics of the Extraction Process

Figures 7, 8, 9, and 10 present the physical results of the pith extraction process before and after optimization, highlighting changes in product quality and environmental impact. Key indicators—percent and total losses, pith moisture content, and fineness modulus—were measured and compared across both conditions. These comparisons showed whether the optimized machine settings reduced waste, improved pith quality, and enhanced overall extraction performance.

3.7.1 Percent Losses

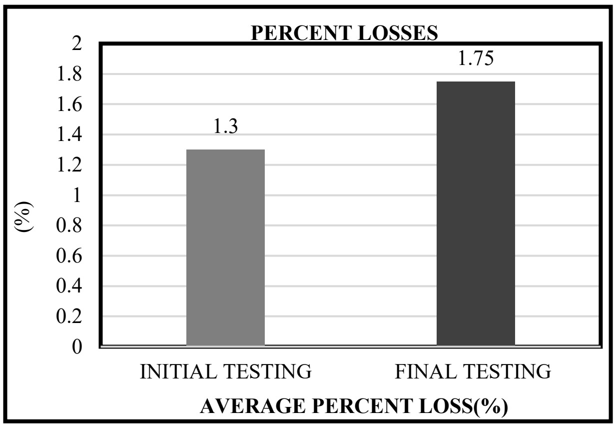

Figure 7. Percent Losses

Figure 7 shows an increase in average percent losses from 1.3% in the initial testing to 1.75% in the final testing. This 0.45% rise is attributed to the change in teeth type: the sharp nail-type teeth used initially enabled more efficient rasping, while the dull, flat screw-type teeth in the final testing were less effective, resulting in more unprocessed material. Similar observations were reported by Bagasbas and Barroca (2020b), noting the significant effect of pointed tooth tips on pith processing performance.
This result emphasizes the importance of tooth design and sharpness, as greater material loss reduces yield and overall productivity. Ensuring proper tooth selection and maintenance is essential for minimizing waste and achieving consistent machine performance.

3.7.2 Losses (kg)

As shown in Figure 8, the reduction in losses may be attributed to the extended machine cover, which improved containment and guided the rasped material more effectively. This modification minimized spillage and uncollected residue, resulting in better material recovery.
The decreased loss indicates improved machine performance and demonstrates the value of iterative design. Even small structural adjustments can enhance efficiency, reduce waste and operating costs, and support more sustainable postharvest equipment development.

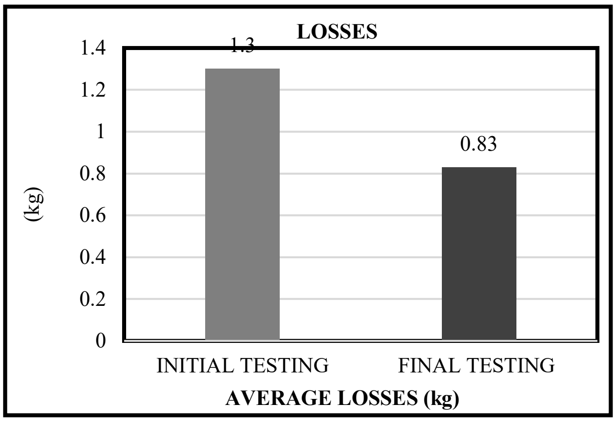

Figure 8. Losses (kg)

3.7.3 Moisture Content

Figure 9 shows a slight decrease in MCwb from 58.65% to 55.95% and a more notable drop in MCdb from 141.90% to 127.15%. These reductions reflect gradual moisture loss due to natural drying during handling, exposure to ambient conditions, and moisture released during extraction. The larger decline in MCdb indicates more effective removal of bound water, which improves mechanical separation and reduces the energy needed for subsequent drying.
Overall, this trend suggests better product quality and improved readiness for further processing. It also highlights the need for consistent handling and optimized extraction parameters to maintain effective moisture management.

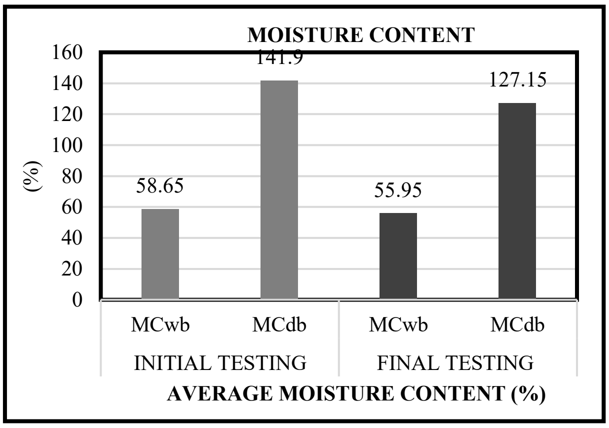

Figure 9. Moisture Content

3.7.4 Fineness Modulus

Figure 10 shows a decrease in FM from 1.86 during initial testing to 1.20 in the final testing, indicating finer and more uniform particles. This improvement is closely linked to the lower moisture content observed in the final samples. Higher moisture in the initial samples caused clumping, which reduced sieving efficiency and produced coarser material.
With lower moisture, the final samples flowed more freely and exhibited less particle cohesion, enabling finer particles to pass through the sieve more effectively. These results highlight the strong influence of moisture content on sieving performance and underscore the importance of proper moisture control in achieving consistent, high-quality sago pith.

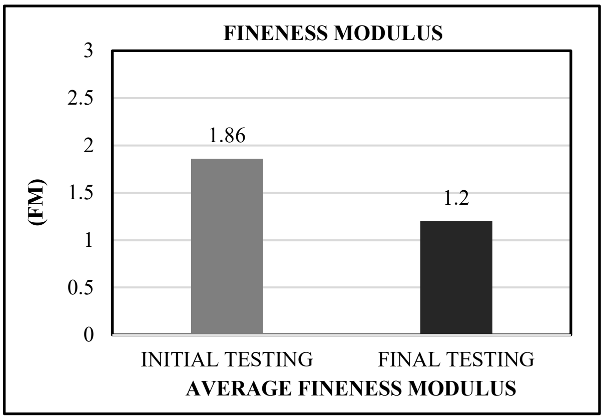

Figure 10. Fineness Modulus

4. Conclusion

This study optimized the operational parameters of a mechanical sago pith extractor using Response Surface Methodology (RSM) and a Randomized Complete Block Design (RCBD). Key performance indicators included extraction capacity, extraction efficiency, fineness modulus, and energy consumption. RSM results showed that tooth configuration—particularly the number of teeth—had a significant effect on machine performance. The optimal setting, consisting of eight teeth and a 14-inch log length, produced an extraction capacity of 1,065.07 kg/hr, an efficiency of 85.06%, a fineness modulus of 1.99, and an energy consumption of 0.0018 kWh/kg.

These findings demonstrate that proper optimization substantially improves machine efficiency and productivity, yielding high capacity while maintaining acceptable energy use and product uniformity. Additional improvements in acoustic conditions and moisture regulation further validate the effectiveness of optimized mechanical extraction for sago pith processing. However, performance deviations during final testing—linked to the use of less-sharp teeth—emphasize the machine's sensitivity to component condition. Consistent maintenance and preservation of tooth sharpness are therefore essential to ensure reliable and repeatable operation across production units.

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