



# Journal of Sustainable Engineering & Renewable Energy (JSERE)

VOLUME 1 ISSUE 1 (2025)



PUBLISHED BY  
E-PALLI PUBLISHERS, DELAWARE, USA

## Multi-Objective Optimization of a Coconut Dehusking Machine Using Response Surface Method (RSM)

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### Article Information

**Received:** April 07, 2025

**Accepted:** May 10, 2025

**Published:** September 16, 2025

### Keywords

*Coconut Dehusking, Efficiency, Machine Design, Multi-Objective Optimization, Response Surface Methodology*

### ABSTRACT

Coconut dehusking is a labour-intensive process, necessitating efficient mechanized solutions to enhance productivity and reduce physical strain, this study aimed to optimize a coconut dehusking machine using Design Expert v13.0, a labour-intensive process. A CAD-based model was developed and simulated, and mathematical models were derived using dimensional analysis. The I-Optimal custom design of Response Surface Methodology (RSM) was validated through 22 experimental runs. The results showed strong agreement between the experimental and predicted dehusking efficiencies. The machine achieved a maximum efficiency of 89.5% and a grating capacity of 189 nuts/hr. In comparison, the I-Optimal model predicted an optimal efficiency of 85.7% and a capacity of 179 nuts/hr at 121.014 rpm, spike angle of 57°, and spike length of 12.7 mm. Frame deformation under maximum load was minimal at 0.05289 mm. The RSM-based approach effectively optimized the coconut dehusking machine, supporting the design of efficient, durable dehusking systems for agricultural applications.

### INTRODUCTION

As the 19th greatest producer in the world with an annual yield of 224,184.26 tonnes, the coconut (*Cocos nucifera*) is an essential perennial crop in tropical regions that greatly boosts economic growth, employment, and food security in nations like Nigeria (FAO, 2025). According to Olorunfemi *et al.* (2022) and Ajala and Alexander (2020), coconut is a resource that can be used for a variety of purposes, including food (oil, milk), industrial goods (ropes, soaps), and agricultural by-products. This demonstrates how crucial coconuts are to Nigeria's agricultural economy. Processing coconuts, especially dehusking the process of separating the fibre husk from the shell remains a crucial bottleneck, nevertheless. With an output of only about 100 coconuts per hour, manual dehusking which is frequently done in Nigeria with machetes or spears is time-consuming, labour-intensive, and dangerous (Ovat & Odey, 2019; Yaro *et al.*, 2022). Small-scale farmers are deterred from implementing effective processing techniques because of these ergonomic and financial disadvantages, which include weariness and possible injuries (Deo *et al.*, 2020; Navaneethan *et al.*, 2020). Several mechanical and power-operated dehusking machines have been created worldwide to solve these issues; these machines provide benefits including increased throughput, enhanced safety, and decreased drudgery (Olorunfemi *et al.*, 2022; Pascua *et al.*, 2018). The research has shown that machines using spiked rollers, blades, or hydraulic systems may produce 70–240 coconuts per hour with efficiency ranging from 85.23% to 92.5% (Ajala & Alexander, 2020; Onyenanu & Uwadibe, 2024; Ovat & Odey, 2019). Despite these developments, low-income farmers in Nigeria are unable

to afford many of the current machinery due to its high cost, incompatibility with local coconut varieties (West African Tall, hybrid), and complicated maintenance needs (Onyenanu & Uwadibe, 2024; Yaro *et al.*, 2022).

Though problems like shell breakage and limited flexibility still exist, locally designed machines, such as those that use mild steel rollers and spur gears, have shown promise with efficiency up to 92.5% and low production prices (Ajala & Alexander, 2020; Onyenanu & Uwadibe, 2024). Additionally, indigenous designs have not fully benefited from the incorporation of contemporary methods like Response Surface Methodology (RSM) and Computer-Aided Design (CAD), which might improve performance while lowering manufacturing costs (Navaneethan *et al.*, 2020). Using Autodesk Inventor for 3D CAD modelling and I-Optimal RSM for experimental design, this work attempts to close these gaps by developing and optimizing a coconut dehusking machine specifically for Nigerian farmers. This study integrates CAD simulation, dimensional analysis, and empirical testing to create an affordable, user-friendly machine, in contrast to other studies that frequently concentrate on either mechanical design or performance assessment (Ajala & Alexander, 2020; Ovat & Odey, 2019). The study aims to attain greater efficiency and throughput in comparison to human techniques (100 coconuts/hr) and current local machines (120.6 coconuts/hr) by utilizing locally produced materials, such as mild steel, and improving structural balance (Onyenanu & Uwadibe, 2024).

This study is significant because it has the potential to improve the productivity of coconut processing, lower health concerns, and set fabrication standards, all of which would benefit small-scale enterprises in Nigeria's

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coconut belt and encourage agricultural automation. Although research on unrelated processes, such as bitumen modification or microalgae flocculation, emphasizes the adaptability of RSM and material optimization, it is not directly relevant in this context (Al-Sabaei *et al.*, 2022;

Machado *et al.*, 2022). However, this study focuses on using Response Surface Method (RSM) solutions to achieve the requirements of coconut dehusking machine performance.

**LITERATURE REVIEW**

**Table 1:** Summary Review Table

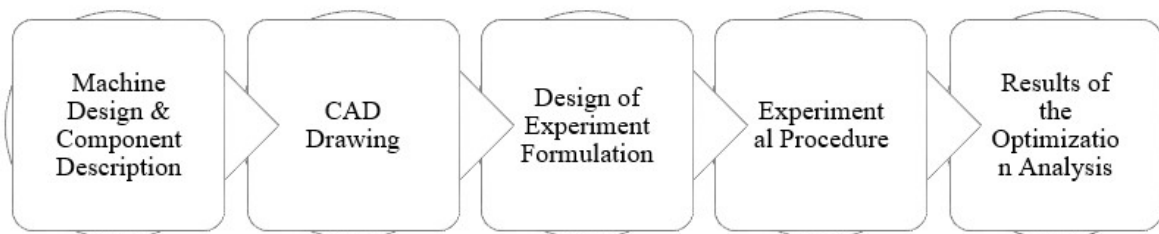
Author(s)	Year	Title / Focus	Methodology / Tools Used	Key Findings	Relevance to Present Study
Olorunfemi <i>et al.</i>	(2022)	Development of a Modified Dehusking Machine for Nigerian Coconut Varieties	Fabrication with local materials; 20 experimental runs; performance evaluation	Efficiency of 90.4%; 70–80 coconuts/hour; affordable (₦167,000); suitable for sub-Saharan use	Relevant design and performance metrics for a locally adaptable coconut dehusking machine
Navaneethan <i>et al.</i>	(2020)	Review of Coconut Dehusking and Cutting Machines	Review of existing mechanisms (motor, gears, rollers)	Time-saving vs. manual method; recommendation to enhance design for wider applicability	Provides design insights and a comparative understanding of household dehusking machines
Idogho <i>et al.</i>	(2025)	Optimization of a Sustainable Virgin Coconut Oil Extraction Machine for Rural Communities	SolidWorks Dassault 2023 and optimized via Response Surface Methodology (RSM)	The optimized conditions led to an oil yield of 1.412 kg/L, a mass balance of 2.608 kg, an energy consumption of 22.53 kWh, and a machine efficiency of 65.67%	The study underscores the machine’s potential to improve rural livelihoods by reducing production costs, ensuring consistent oil quality, and aligning with sustainable practices.
NelsonEkanem <i>et al.</i>	2020	Optimization of Mechanically Expressed Coconut (Cocos Nucifera L.) Oil Using Response Surface Methodology	Response Surface Methodology	Predicted optimum oil yield of 43.67% at moisture content of 13.6% wet basis, temperature of 77.5oC, duration of 19.0 minutes and pressing time of 5.8 minutes was obtained.	It was established that the processing parameters (moisture content, pressing time, heating temperature and heating time) had significant effects on the quantity of oil recovery from coconut.
Deo <i>et al.</i>	(2020)	Performance Evaluation of Power-operated Deshelling Machine	Evaluation of three coconut varieties using a 1 hp motor and a chain-sprocket gear reduction	89–92% efficiency; 141–148 nuts/h; minimal difference across varieties	Offers performance benchmark and supports automated de-shelling applicability
Aje & Ogbeche	(2019)	Development & Performance Evaluation of Coconut Dehusking Machine	Use of galvanized pipe rollers, spur gears, and a flywheel-pulley system	Efficiency: 92.5%; Capacity: 120.6 nuts/h; minimal coconut damage	Strongly supports mechanical design and operational performance metrics
Pascua <i>et al.</i>	(2018)	Coconut Dehusking Performance Optimization	RSM, Box-Behnken design (15 runs), regression modelling	Optimum force: 109.59N; Efficiency: 85.23%; Capacity: 240 nuts/h; power: 6.41kW	Demonstrates the use of RSM for optimizing mechanical dehusking parameters

Özkan Karabacak <i>et al.</i>	(2024)	Coconut husk: A sustainable solution for eco-friendly packaging applications	Composition analysis, extraction and processing techniques, material testing for tensile strength, elongation, CO <sub>2</sub> and oxygen permeability, and thermal stability	Polyphenols from young coconuts reduced CO <sub>2</sub> gas permeability by 81% and oxygen transmittance by 79%; biocomposite films with 3% coir cellulose nanofibers showed improved tensile strength, elongation, and thermal stability; demonstrated antimicrobial properties and waste reduction	Highlights the sustainable use of coconut husk, relevant for exploring husk by-products from dehusking processes in machine optimization for eco-friendly applications
Naliapara <i>et al.</i>	(2023)	The Technological Developments in Power Operated Coconut ( <i>Cocos nucifera</i> L.) Dehusking and Deshelling Machines: A Review	Literature review of machine designs, analysis of working mechanisms, and evaluation of machine features and capacities	Identified various power-operated dehusking and deshelling machines, reducing labor intensity and worker harm; detailed mechanisms and capacities to guide future machine development	Provides a foundation for understanding current dehusking machine technologies, critical for optimizing machine design using RSM in the present study

**MATERIALS AND METHODS**

Machine Design involves creating a detailed plan for a machine, including its structure, functionality, and component specifications. Engineers and designers collaborate to ensure the machine meets performance criteria, considering factors like material selection, durability, and operational efficiency. A precise digital model is developed using Computer-Aided Design (CAD) software, allowing for visualization, simulation, and modification before physical prototyping (Onyenanu & Ezechukwu, 2024). A systematic plan is created

for experiments to test the machine’s performance, defining variables, objectives, and methodologies for analysis and optimization. The experiments are executed in a controlled environment, and data is collected on performance, such as speed, efficiency, or stress resistance. Optimization analysis results are analysed to identify areas for improvement, enhancing the machine’s performance, reducing costs, or improving reliability. (Madukasi *et al.*, 2025; Oboh, 2018; Onyenanu *et al.*, 2024). Figure 1 describes the design pathway methodology for the research.



**Figure 1:** Design Pathway for the Methodology

**Machine Design & Components**

As shown, the power produced by the prime mover is transmitted to the system through a series of chain drives, sprockets, and chains. The power transmitted into the lower roller was transmitted to the upper roller through a sprocket-chain connection. The fixed rollers have spikes

designed to penetrate the husk and pull it apart (Naliapara *et al.*, 2023; Onyenanu *et al.*, 2025; Onyenanu *et al.*, 2024). To facilitate the dehusking of different sizes of coconuts, an adjustable tension lever will push the nuts through springs that are attached adjacent to the two rollers. The husk was stopped by spikes that are connected to the

frame, and the husk was discharged outside the machine or in front of the operator. The de-husked coconut was dropped down to the discharge chute, and if the de-husked coconut didn't fall freely, an adjustable lever was provided to facilitate discharging (Onyenanu & Uwadibe, 2024; Ovat & Odey, 2019). Figure 2 shows a pictorial representation of a coconut dehusking machine.



**Figure 2:** Coconut dehusking machine

The coconut de-husking machine comprises several key components, primarily constructed from mild steel for its high tensile strength and machinability, with specifications tailored for efficient operation. The structural base, made from SAE-950A alloy mild steel angle iron (45x45x4 mm), measures 592 mm in length, 500 mm in width, and 750 mm in height. The hopper, with dimensions of 500 mm total length, 375 mm width, 140 mm height, and 1 mm thickness, channels coconuts into the machine. The discharge chute, also 1 mm thick mild steel, measures 488 mm long, 438 mm in width, and 350 mm in height (Onyenanu *et al.*, 2024). The de-husking shaft, a 600 mm long mild steel round bar with a 25 mm diameter, includes an 8x3 mm keyway. SKF UCP 205 pillow block bearings (25 mm inside diameter, 90 mm outside diameter, 30 mm thickness) support the shaft. Power transmission occurs through a chain drive system, which is made up of a driving sprocket (76 mm pitch diameter, 18 teeth) connected to the gear motor and a driven sprocket (85 mm pitch diameter, 20 teeth) mounted on the shaft. Gears (190 mm diameter, 20 mm thick, 28 grooves) connect the driving and driven shafts (Onyenanu *et al.*, 2025). The electric gear motor (model YC 112L-4, 1.5 kW, 230 V, 1450 rpm, 1:15 ratio) drives the system. The de-husking drum, constructed from mild steel, has a 320 mm length, 103/115 mm inner/outer cylindrical diameters, and 6 mm thickness. Mild steel bolts and nuts secure components, while polyester fibre is used for its durability and chemical

resistance, ensuring no contact with edible coconut parts to avoid contamination.

### Sample Preparation

The experimental design involved selecting mature coconuts for each run to ensure consistency in evaluating the machine's performance. Before testing, the coconuts were inspected to remove defects. The dehusking machine was set up with specified spike angles, lengths, and rotational speeds based on the experimental design. The coconuts were fed into the hopper and passed through spiked rollers. After dehusking, the remaining husk was manually removed, and both the dehusked coconuts and detached husks were weighed. The dehusking time was recorded to compute throughput and efficiency. This process was repeated systematically for all 20 runs defined by the I-optimal custom design. Figure 3 shows a sample of coconut dehusked.



**Figure 3:** Dehusked Coconut with its husk

To develop an optimal mix for the sample, an optimal (custom) design, which is a specialized form of randomized design from the surface response method (RSM), will be employed. These I-optimal designs (also called IV or Integrated Variance) provide lower average prediction variance across your region of experimentation. I-optimality is desirable for response surface methods (RSM) where prediction is important. The algorithm picks points that minimize the integral of the prediction variance across the design space (Onyenanu & Ezechukwu, 2024; Utu *et al.*, 2024). For this design, the coconut dehusking machine's optimum performance will be investigated to fine-tune two product attributes, which are measured as responses from a design experiment.

Response 1: Dehusking Throughput (Kg/Sec)

Response 2: Dehusking Efficiency (%)

Again, the three primary factors that affect the performance of the machine vary as shown:

110 RPM ≤ (Dehusking Speed) ≤ 150 RPM ....@ (3 levels)

50 degree ≤ (Spike Angle) ≤ 90 degree ....@ (3 levels)

10mm ≤ (Spike length) ≤ 20 degree ....@ (3 levels)

The experiment will be conducted with the Design Expert Software 13.0. The optimal (custom) design will be employed in such a way that it develops a flexible design

structure to accommodate custom models, categorical factors, and irregular (constrained) regions. Runs are determined by a selection criterion chosen during the build.

**Experimental Procedure**

The dehusking drum with a spike angle of 50 degrees to the horizontal is mounted on the machine while experimenting. The Spike length will be varied at 20 mm, 15mm, and 10mm. The dehusking speed will also be varied using a speed reducer at 110 rpm, 130 rpm, and 150 rpm. As the samples will be fed into the machine, the dehusking time will be recorded. The husk will be collected through the discharge chute, and the remaining husk on the coconut shell will be removed by hand. Their weights will be recorded. The corresponding dehusking time will be taken. This will be repeated for blade spike angles of 70 degrees and 90 degrees to the horizontal.

Dehusking Efficiency: The dehusking efficiencies of the machines will be checked to establish the extent the machines can dehusk concerning the different spike angles and speeds. This will be achieved using equation (1), thus;

$$De = D_c T_i \times 100 \dots \dots \dots \text{Eqn 1 (Garcia et al., 2021)}$$

Where:

De = De-husking Efficiency (%)

$D_c$  = Number of de-husked coconuts

$T_i$  = Total number of coconut inputs

**Dehusking Capacity**

The dehusking capacity of the machine will be checked to establish the quantity of coconuts the machine can dehusk at a given time. This will be achieved using equation (2), thus;

$$C_d = D_n / T_o \dots \dots \dots \text{Eqn.2 (Deo et al., 2020; Garcia et al., 2021)}$$

Where

$C_d$  = de-husking Capacity (no. of nuts/ h)

$D_n$  = de-husked nuts

$T_o$  = time of operation (h)

**Optimization Using the I-Optimal Mixture Design**

I-optimal designs (also called IV or Integrated Variance) will be utilized to determine the coconut dehusking machine's optimum performance, considering two major responses, which are the dehusking capacity and dehusking efficiency of the machine. The statistical parameters used in evaluating and selecting the best-fitted model are coefficient of determination ( $R^2$ ), adjusted coefficient of determination (adjusted  $R^2$ ), predicted coefficient of determination (predicted  $R^2$ ), coefficient of variation (C.V), standard deviation, predicted residual sum of squares (PRESS), lack-of-fit, and regression data (P-value and F-value) (Goos et al., 2016; Muthuveni et al., 2024). The statistical analysis also constructs an equation from the best-fitted model. From the equation, the positivity of the coefficient presents the positive contribution toward the response, and vice versa. Also, a contour plot and response surface graph for each response will be generated by Design-Expert Software Version 13.0 for a better explanation.

**RESULTS AND DISCUSSION**

**Results of the Optimization Analysis Using Response Surface Methodology**

A preliminary study on the performance evaluation of the coconut dehusking machine was done by investigating the major parameters that affect the performance of the machine. three excipients were chosen for investigation based on their function. Three of them were used as variables in I-optimal custom design as they may affect the responses. The ranges of variables were also studied by using I-optimal custom design in Design Expert software 13.0. Table 1 shows the summary data table of the actual design after the experiment.

**Table 2:** Summary of the Actual Design Table for the Optimization

	Factor 1	Factor 2	Factor 3	Response 1	Response 2
Run	A: Dehusking Speed	B: Spike Angle	C: Spike Length	Machine Efficiency	Machine Throughput
	RPM	Degrees	mm	%	Kg/Sec
1	150	90	20	81.3	179
2	110	70	10	76.9	170
3	150	70	15	88.8	184
4	130	50	10	87.2	179
5	150	90	10	83.4	182
6	150	50	20	87.1	182
7	130	90	10	73.9	174
8	130	50	15	89.1	180
9	130	50	15	88.9	179
10	150	70	15	89.2	189
11	150	50	10	87.9	173
12	130	70	20	79.6	175
13	110	50	20	86.5	179

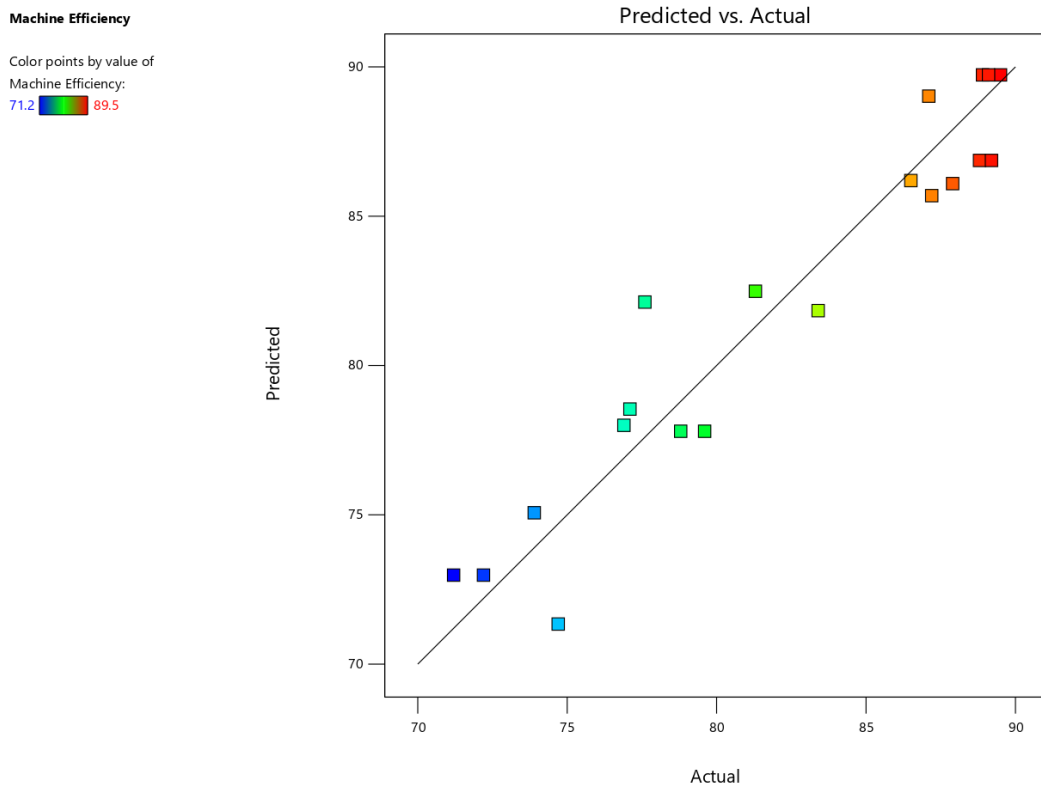
14	150	70	10	77.6	177
15	110	90	15	71.2	173
16	130	70	10	77.1	175
17	130	70	20	78.8	178
18	130	50	15	89.5	183
19	110	90	10	74.7	159
20	110	90	15	72.2	169

**Predicted and Actual Results for the Two (2) Responses Machine Efficiency**

Using the design expert software, the experimental design table was improved through optimization. Coded equations were generated for each scenario, which were then utilized to estimate the anticipated outcomes of the experiment. Figure 4 exhibits a graph that compares the predicted values with the actual results obtained from the experiment. The graph verifies a significant similarity

between the predicted and actual values, particularly in the machine efficiency experiment, which the figure also presents a detailed analysis of the dehusking efficiency of a coconut dehusking machine, comparing actual and predicted values across 20 experimental runs.

The figure helps identify model accuracy, outliers, and influential points, with runs 1, 6, and 14 flagged for high influence or residuals, suggesting potential areas for refinement.



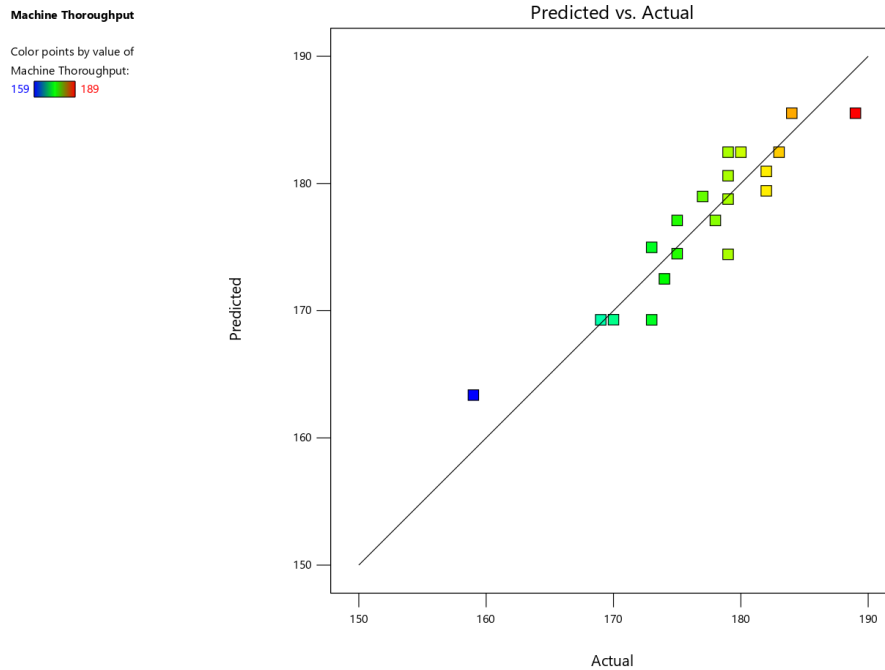
**Figure 4:** Predicted and Actual Values for the Dehusking Efficiency

**Dehusking Throughput**

Figure 5 visually depicts the comparison between the predicted and actual results of the experiment, focusing on the measurement of the machine throughput. Again, this graph highlights a significant similarity between the projected and observed values, especially within the scope of this particular experiment.

The dehusking throughput performance of a coconut dehusking machine, as seen in the figure below, compares

actual and predicted values across 20 experimental runs. The actual throughput ranges from 159.00 to 189.00 units, with likely coconuts per unit time. The predicted throughput ranges from 163.37 to 185.53, with residuals indicating the difference between actual and predicted values. The figure reveals the model’s predictive performance, with runs 1, 6, and 19 showing notable residuals or influence, suggesting areas for further machine or model optimization.

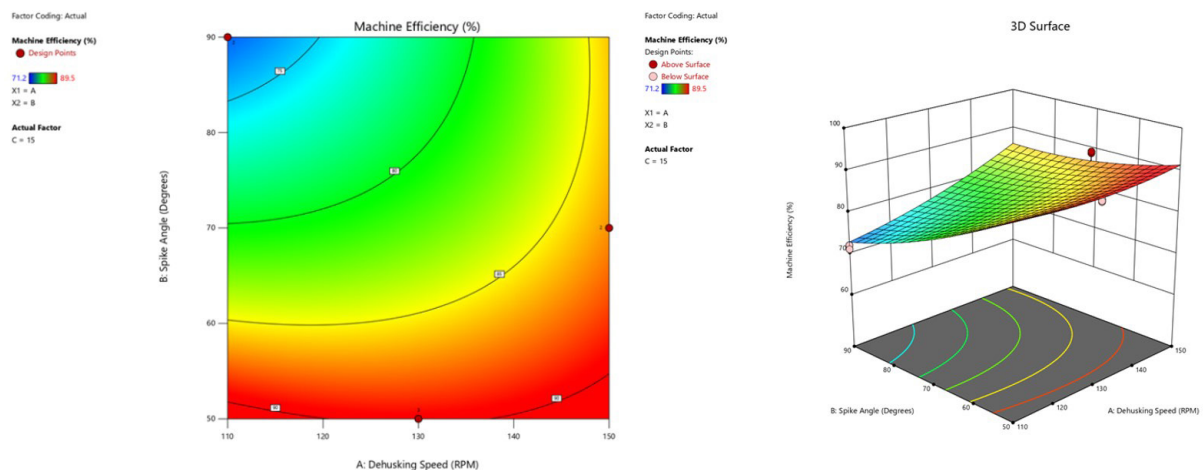


**Figure 5:** Predicted and Actual Values for the Dehusking Throughput

**Effect of the Selected Factors on the Response**

Figure 6 [A] The contour diagram illustrates the relationship between three key variables: dehusking speed (A), spike angle (B), and spike length, and their impact on the dehusking efficiency of the machine. By plotting these factors in a 2D space, the diagram reveals optimal combinations where efficiency is maximized, helping engineers identify the best operational settings. The colour gradients or contour lines likely indicate efficiency levels, with peaks showing the most effective

configurations. [B] The 3D surface plot provides a more dynamic visualization of how dehusking speed, spike angle, and spike length interact to influence efficiency. Unlike the contour plot, this graph adds depth, showing how changes in one variable affect the response across multiple dimensions. The peaks and valleys on the surface highlight optimal and suboptimal conditions, offering a clearer understanding of complex interactions (Erhimona *et al.*, 2023; Madukasi *et al.*, 2025; Maheswari *et al.*, 2021).



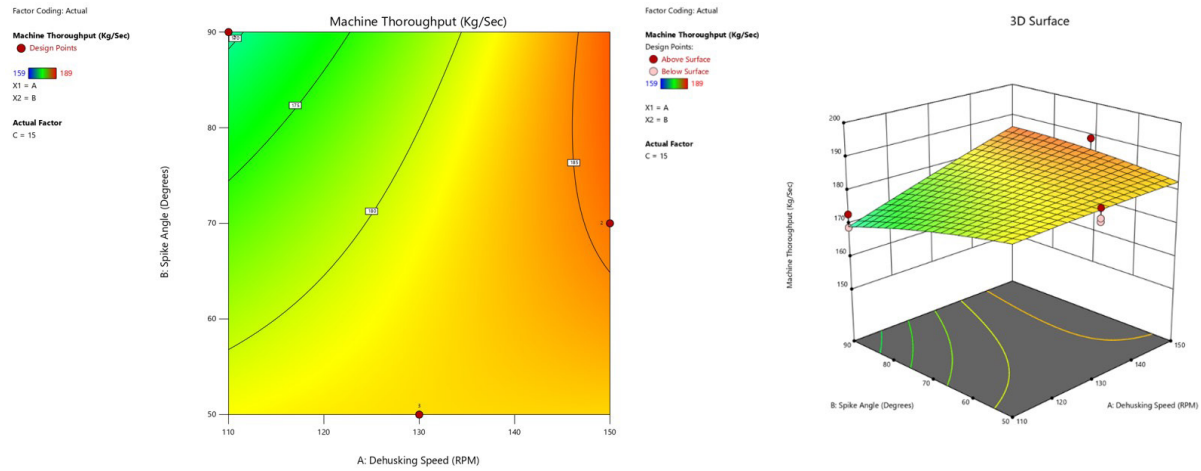
**Figure 6:** [A] Contour Diagram and [B] 3D Surface Plot of the Relationship Between Three Variables for the Dehusking Efficiency of the Machine

This contour diagram (left) shifts focus to dehusking throughput, analysing how the same three variables impact the machine’s productivity (coconuts processed per hour). The plot helps identify settings that balance speed and precision, ensuring high throughput without

compromising efficiency. Contour lines may indicate zones where throughput is highest, guiding performance tuning. The corresponding 3D plot (right) visualizes throughput as a function of the three variables, emphasizing how adjustments in one parameter (spike

angle) alter productivity when combined with others. The surface's curvature reveals nonlinear relationships, such as diminishing returns at extreme settings, aiding in

fine-tuning the machine for maximum output (Nelson Ekanem *et al.*, 2020; Yunusa *et al.*, 2025).



**Figure 7:** [A] Contour Diagram and [B] Showing the 3D Diagram of the Relationship Between Three Variables to the Dehusking Throughput of the Machine

### Coefficients in Terms of Coded Factors

The equation in terms of coded factors can be used to make predictions about the response for given levels of each factor. By default, the high levels of the factors are coded as +1, and the low levels are coded as -1. The coded equation is useful for identifying the relative impact of the factors by comparing the factor coefficients (Machado *et al.*, 2022; Onyenanu & Ezechukwu, 2024). Again, the equation in terms of actual factors can be used to make predictions about the response for given levels of each factor. Here, the levels should be specified in the original units for each factor. This equation should not be used to determine the relative impact of each factor because the coefficients are scaled to accommodate the units of each factor, and the intercept is not at the centre of the design space.

### Dehusking Efficiency

**For the Final Equation in Terms of L\_Pseudo Components, the Model is Written as**

$$\text{Machine Efficiency} = 82.02 + 3.33A - 5.88B - 0.3717C + 3.18AB + 1.27AC - 0.5704BC + 1.52A^2 + 1.84B^2 - 3.85C^2 \quad (1)$$

**Thus, the Final Equation in Terms of Actual Components is Written as**

$$\text{Machine Efficiency} = 225.36410 - 1.56937 [\text{Dehusking Speed}] - 1.88621 [\text{Spike Angle}] + 3.29373 [\text{Spike Length}] + 0.007958 [\text{Dehusking Speed} * \text{Spike Angle}] + 0.012664 [\text{Dehusking Speed} * \text{Spike Length}] - 0.005704[\text{Spike Angle} * \text{Spike Length}] + 0.003803 [\text{Dehusking Speed}]^2 + 0.004594[\text{Spike Angle}]^2 - 0.153837 [\text{Spike Length}]^2$$

### Dehusking Throughput

**For the Final Equation in Terms of L\_Pseudo Components, the Model is Written as**

$$\text{Machine Throughput} = 181.31 + 4.56A - 2.16B + 1.31C + 3.95 AB - 0.2838AC - 1.20BC - 0.3449A^2 - 1.01B^2 - 5.52C^2 \quad (4.5)$$

**Then, the Final Equation in Terms of Actual Components is Written as**

$$\text{Machine Throughput} = 150.44292 - 0.196705 [\text{Dehusking Speed}] - 0.858595 [\text{Spike Angle}] + 8.09451 [\text{Spike Length}] + 0.009878 [\text{Dehusking Speed} * \text{Spike Angle}] - 0.002838 [\text{Dehusking Speed} * \text{Spike Length}] - 0.011971 [\text{Spike Angle} * \text{Spike Length}] - 0.000862 [\text{Dehusking Speed}]^2 - 0.002529 [\text{Spike Angle}]^2 - 0.220870 [\text{Spike Length}]^2$$

### Analysis of Variance (ANOVA) of the Response

The ANOVA of the responses in Table 3 shows that the Model F-value of 11.64 signifies a significant model, indicating a low probability of being influenced by noise. P-values below 0.0500 indicate the significance of terms, while values above 0.1000 suggest their insignificance. Reducing the model might be beneficial if there are many insignificant terms. The R<sup>2</sup> value of 0.9129 and 0.8344 demonstrates a strong correlation between significant terms and density value. For a reliable model, it is desirable to have an Adeq Precision ratio above 4. The Model F-value of 6.67 indicates a significant model, with a 1.19% chance of it being due to noise. P-values below 0.0500 indicate significant model terms. Model reduction may improve the model if there are many insignificant terms. This method was utilized to predict if there is any significant difference in the mean of the experiment in the table below.

**Table 3:** ANOVA of the responses

	Intercept	A	B	C	AB	AC	BC	A <sup>2</sup>	B <sup>2</sup>	C <sup>2</sup>	R <sup>2</sup>
Machine Efficiency	82.016	3.33029	-5.8804	-0.371662	3.18321	1.26639	0.570385	1.52133	1.83774	-3.84591	
p-values		0.0029	< 0.0001	0.6593	0.0144	0.2532	0.5822	0.2772	0.1764	0.0145	0.9129
Machine Thoroughput	181.311	4.55934	-2.16181	1.30747	3.951	-0.28383	-1.19706	-0.344892	-1.01146	-5.52175	
p-values		0.0019	0.0745	0.2434	0.0174	0.8373	0.3765	0.8439	0.5485	0.0082	0.8344

**Comparative Analysis**

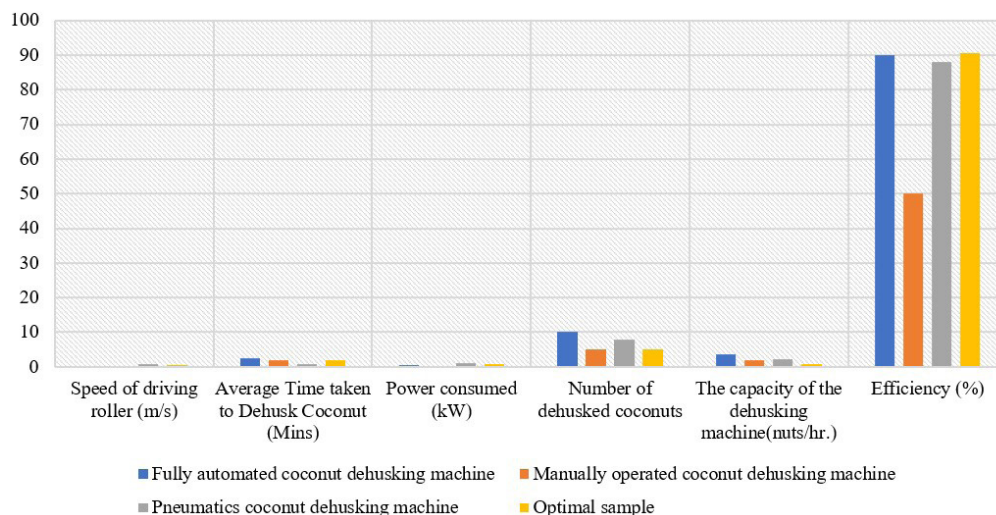
In a comparative analysis of coconut dehusking machines, three types were evaluated: fully automated, manually operated, and pneumatic machines. This

analysis underscores the advantages and limitations of each dehusking machine type, offering valuable insights into their performance in terms of speed, power consumption, capacity, and overall efficiency.

**Table 4:** Comparative Analysis of Different Coconut Dehusking Methods

Parameter	Fully automated coconut dehusking machine	Manually operated coconut dehusking machine	Pneumatics coconut dehusking machine	Optimal sample
Speed of driving roller (m/s)	0.11	0.3	0.8	0.412
Average Time taken to Dehusk Coconut (Min)	2.5	2	0.75	1.99
Power consumed (kW)	0.444	0.2	1	0.8
Number of dehusked coconuts	10	5	8	5
The capacity of the dehusking machine(nuts/hr.)	3.7	2.015	2.33	0.66
Efficiency (%)	90	50	88	90.5

**Various Coconut Dehuskers Parameter Vs Optimal Sample**



**Figure 8:** Comparative Analysis of Various Coconut Dehuskers and Optimal Sample

## CONCLUSION

The study effectively improved a coconut dehusking machine using CAD modelling and I-Optimal Response Surface Methodology (RSM), resulting in notable performance gains. While the I-Optimal model projected optimal performance at 85.7% efficiency and 179 nuts/hr at a speed of 121.014 rpm, spike angle of 57°, and spike length of 12.7 mm, the improved machine reached a maximum efficiency of 89.5% with a throughput capacity of 189 nuts/hr. Structural integrity was confirmed by the smallest frame deformation of 0.05289 mm. The dependability of the model was validated by the ANOVA and regression models, which showed great model accuracy ( $R^2 = 0.9129$ ) and significant alignment between expected and actual outcomes. Spike angle was shown to be a crucial component affecting throughput and efficiency. The values show the advantages of using RSM and CAD tools in the optimization of the machine design and its performance. The versatile and sustainable design of coconut processing machines, fabricated using locally sourced mild steel and cost-efficient components, offers a viable alternative to costly imported machines. This machine enhances productivity by 89% over manual methods and reduces operational hazards and fatigue. Its adaptable parameters allow for customization based on coconut varieties and user needs, making it both affordable and sustainable, setting a precedent for agricultural mechanization in coconut-producing regions.

## Recommendations

The dehusking machine can be improved by incorporating an automatic system to prevent coconuts from being thrown off the hopper. This energy-efficient and solar-powered design can facilitate processing in rural areas. Developing specific model constants for different coconut species can refine and standardize the machine's performance. Additionally, incorporating a cycle process for collecting coconuts after dehusking can streamline operations and make the process more efficient.

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