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Enhancing Coconut Processing Efficiency: Design and Evaluation of A Cost-Effective Coconut De-Husking Machine

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ABSTRACT

Coconut (*Cocos nucifera*) plays a crucial role in agricultural economies, particularly in coconut-producing regions, where traditional de-husking methods are labor-intensive and time-consuming. This study focuses on the design, fabrication, and evaluation of a coconut de-husking machine aimed at improving processing efficiency, reducing labor demands, and increasing throughput. The machine was designed to address key performance factors such as frame stability, blade strength, and spring tension. Testing demonstrated that the machine consistently outperformed manual methods, reducing de-husking time to an average of 96.4 seconds compared to 164.8 seconds for traditional techniques. The machine achieved an efficiency rate of 80%, with a throughput capacity of 0.0086 kg/s, significantly higher than the manual method's 0.005 kg/s. Additionally, the machine's cost, approximately N32,000, makes it accessible to smallholder farmers, offering a practical solution for improving productivity and sustainability in coconut farming. The study highlights the potential for mechanized de-husking to transform traditional practices, reduce labor costs, and contribute to economic growth in coconut-rich regions. Future research should explore further optimization of the machine design and its adaptability to different coconut varieties and moisture levels, ensuring broad applicability in diverse farming contexts.

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INTRODUCTION

Coconut (*Cocos nucifera*) is recognized as one of the most versatile and economically significant perennial plants globally, serving various purposes from food production to industrial applications (Ohler et al., 2002). The coconut fruit, classified as a large drupe, comprises three distinct layers: the exocarp, mesocarp, and endocarp, which encase the seed. Notably, coconut milk is abundant in unripe fruits, diminishing as the fruit matures (Nwankwojike et al., 2012). The utilization of coconut shells extends to fuel production and as a source of energy through gasification, highlighting the fruit's multifaceted economic value. Despite its importance, the de-husking process remains a significant challenge, particularly for rural farmers who rely on traditional methods, such as machetes or metal spikes, which are labor-intensive and pose safety risks (Gunn et al., 2011).

The development of mechanical solutions, such as the metal spike, aimed to mitigate the dangers associated with manual de-husking. However, these innovations primarily focused on extracting coconut meat rather than addressing the broader issues of efficiency and safety in the de-husking process (APCC, 1996). Recent advancements, such as the machine designed by Nwankwojike et al. (2012), which employs dual blades for automatic de-husking, have emerged. Nonetheless, these machines often present complexities in operation and maintenance, rendering them prohibitively expensive for many coconut farmers. The unreliability of public electricity supply, particularly in rural areas of Nigeria, further complicates the adoption of such technologies (Anih, 2008).

Labor-intensive traditional de-husking methods not only lead to physical strain and muscular pain among workers but also result in significant time consumption, underscoring the urgent need for a more efficient and cost-effective solution (Gunn et al., 2011). The existing literature highlights a critical gap in the design of de-husking machines that cater specifically to the needs of coconut farmers, particularly in terms of processing capacity, labor savings, and affordability. For instance, Pandiselvam (2024) discusses the engineering properties of coconuts and their implications for designing efficient coir fiber extraction machines, emphasizing the necessity for machines that can accommodate varying coconut sizes to ensure effective de-husking.

Moreover, the economic challenges faced by coconut farmers, including high labor costs and fluctuating market prices, necessitate the development of innovative solutions that can enhance productivity while reducing operational costs (Zainol et al., 2023). The integration of technology in coconut processing not only promises to alleviate labor burdens but also has the potential to improve the overall economic viability of coconut farming. However, the literature indicates that many existing machines do not adequately address the specific operational challenges faced by farmers, such as the need for reliability and ease of maintenance (Gunawan et al., 2021).

In summary, while the coconut industry holds significant economic potential, the persistent challenges associated with traditional de-husking methods and the limitations of existing mechanical solutions highlight a critical research gap. Addressing this gap through the design of innovative, user-friendly, and cost-effective de-husking machines is essential for enhancing productivity and ensuring the sustainability of coconut farming. Future research should focus on developing technologies that are not only efficient but also accessible to smallholder farmers, thereby fostering economic growth and improving livelihoods in coconut-producing regions.

MATERIALS AND METHODS

Materials

The machine was constructed, tested and evaluated in the department of Agricultural Technology Department, Federal College of Forestry, Ibadan. Some of the fabrication tools used during the operations include; portable grinding machine, try square, welding torch, electrodes, steel measuring tape, hammer, filing machine, cutting plier, engineer vice, drilling machine, and shaper machine. Some of the components of the machine include:

i. A frame … this is the machine bed, it the foundational structure of the machine to provide, stability, rigidity and support.
ii. A two-mouthed de-husker blade … blade having two sharp cutting edges for de-husking.
iii. Coil spring … this is for instant pull back after each operation.
iv. Foot pedal … spiral spring used to store and release mechanical energy and suspension.
v. Metal stand … support structure made from steel.
vi. Seat … armless and backless saddle, designed for the operator's comfort.

Method

Design: the dimensions of the various parts were calculated based on standards and their respective functions.

Frame … An assumed length of 9m, width of 0.09m and a thickness of 0.02 cm were considered.

Mass of frame = density x volume (lbt)

(Where → density of steel (7850kg/m^3), l → length, b → breadth, t →thickness of blade).

M = 7850 x 9 x 0.09 x 0.02 = 127.17 kg.

This was considered capable of carrying the weight of an average human being during de-husking operation.

Seat … it has conical shape with slant length(l) of 0.3m and a base radius (r) of 0.05m.

$Surface\ area\ of\ seat\ (A) = \pi r\ (r + l) = 3.142\ x\ 0.05\ (0.3 + 0.05) = 0.05m2$

Blade … the blade was selected based on strength and hardness. Since the diameter of a coconut fruit is not constant, they range between 40 cm – 30 cm for most, the blade was therefore selected based on the maximum width of a coconut fruit. From theory, the machete could require the exertion of a maximum force as much as 1,000N to de-husk the most matured coconut fruit; hence, the force of the machete would be considered for the blade cutting force.

The following assumptions were made;

Considering the force and exerted by a machete cutter;

Force – 1000N, blade width = 0.05m, blade length = 0.09m

Disc thickness (considering stainless steel) = 0.002m

Mass of blade = density x volume (lbt)

(Where → density of stainless steel (7870kg/m^3), l →length, b → breadth, t →thickness of blade)

$M = 7870\ x\ 0.09\ x\ 0.0\ 5\ x\ 0.002 = 11.1kg$

Therefore, Blade weight = 11.1kg

Coil spring … this was selected based on the tensile strength.

From Hooke's law, F = ke

F = force required to de-husk (N), e = displacement of the spring, k = constant of displacement.

$Therefore\ k = 1000/0.3 = 3333.3N/m$

Pedal … the size of pedal was subjected to the size of blade, while the distance of the pedal from the seat was a function of the height of an average user of the machine.

$F = Ma = Mv/t = M\ (d/t)/t = (M\ x\ d)/t2$

Where F = force applied on the pedal, M = average weight of operator (75kg), d = distance between seat and the pedal (0.45m), t = time in seconds (1sec)

$F = (75\ x\ 0.45)/1^2$

$F = 33.75N$

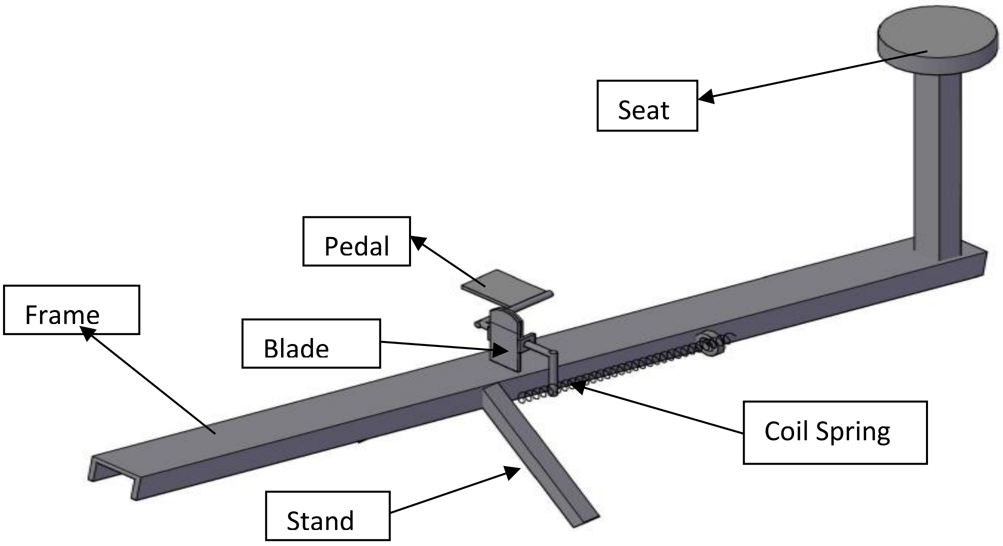

Figure 1: Isometric view of the coconut de-husker

Evaluation parameters

The fabricated machine was compared to the usual crude method of de-husking; the following parameters were considered in the comparison:

i. Throughput capacity … it is the quantity of de-husked coconut divided by the time taken.

Throughput = number of de-husked coconut/ time (Kg/s)

ii. De-husking efficiency … The efficiency of the machine was determined using the equation: $Efficiency = C/N \; X \; 100$

Total number of coconuts de-husked = (N), Number of successfully de-husked coconuts = (C) Number of broken/not successfully de-husked coconuts = (U)

iii. Machine cost valuation: for this study, the cost of materials, fabrication, transportation, labor and miscellaneous were considered as the cost incurred for production.

Performance test

The length, width, weight and number of coconuts de-husked per hour were recorded and replicated five (5) times. The speed of de-husking, the throughput capacity and the de-husking efficiency were evaluated. The same procedure was carried by adopting the crude cutlass de-husking method, data was also gotten and evaluated. The results of both de-husking methods were compared and deductions were made.

RESULT AND DISCUSSION

Throughput capacity

The results of the study indicate that the de-husking machine significantly outperformed manual methods in terms of both efficiency and throughput. As shown in Table 1, replicate 1, which featured the smallest dimensions and weight of coconut samples, recorded the shortest de-husking time of 90 seconds using the machine, while replicate 5, with the largest dimensions, took 105 seconds. The average de-husking times for the machine and manual methods were 96.4 seconds and 164.8 seconds, respectively. This stark contrast in performance underscores the potential of mechanization in enhancing productivity within the coconut processing sector. The throughput capacity of the machine was also notably higher, with an average of 0.0086 kg/s compared to 0.005 kg/s for the manual method. This finding aligns with previous research that emphasizes the importance of adopting mechanized solutions to improve efficiency in agricultural processing, particularly in developing regions where labor-intensive methods are prevalent (Varghese et al., 2021).

Figures 2 and 3 illustrate the relationship between the weight of the coconuts and the respective de-husking times for both methods. The data reveal a consistent pattern: as the weight of the coconuts increased, the de-husking time also increased for both the machine and manual methods. However, the machine consistently demonstrated superior performance, completing the de-husking process in significantly less time across all replicates. This observation is consistent with findings from (Varghese et al., 2021), who reported that advancements in coconut processing technology can lead to substantial reductions in processing time, thereby enhancing overall productivity.

Table 1: Performance test result of machine and manual de-husking method

Replicate	Length (m)	Width (m)	Weight (kg)	Time (sec)		Throughput (kg/s)	
				Machine	Manual	Machine	Manual
1	0.33	0.31	0.67	90	160	0.0071	0.0042
2	0.33	0.32	0.70	93	163	0.0075	0.0043
3	0.33	0.33	0.85	94	165	0.0090	0.0052
4	0.35	0.33	0.87	100	166	0.0087	0.0052
5	0.40	0.34	1.00	105	170	0.0095	0.0059
Mean	**0.35**	**0.33**	**0.82**	**96.4**	**164.8**	**0.0086**	**0.005**

Furthermore, Figure 4 depicts the relationship between throughput capacity, weight, and time. The graph indicates that both time and throughput values increase with the weight of the coconuts, suggesting a direct correlation between these variables. However, it is essential to note that while time and throughput may appear correlated, they are not necessarily directly proportional to each other. For instance, if the weight remains constant, an increase in time could lead to a decrease in throughput capacity, and vice versa. This nuanced understanding of the relationship between these variables is crucial for optimizing machine design and operational efficiency in coconut processing.

The efficiency of the de-husking machine was calculated based on the total number of coconuts processed. Out of 15 coconuts, 12 were successfully de-husked, resulting in an efficiency rate of 80%. This efficiency could be influenced by factors such as excessive moisture content or over-dryness of the coconuts, which have been identified as critical parameters affecting the performance of coconut processing machinery (Baka et al., 2020). The challenges associated with moisture content are particularly relevant, as they can significantly impact the mechanical properties of coconuts and, consequently, the effectiveness of de-husking operations.

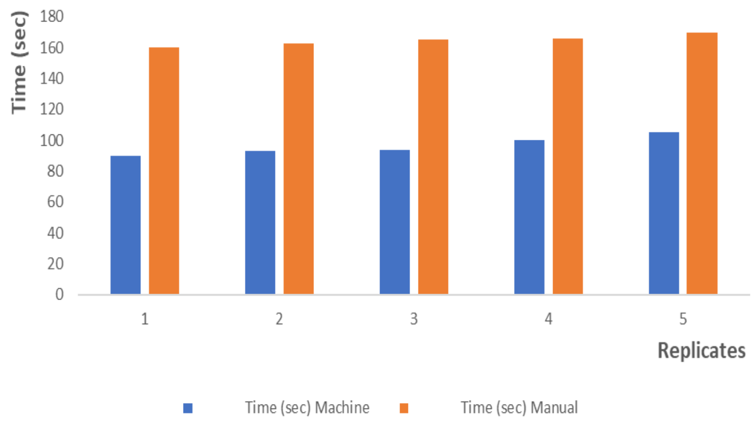

Figure 2: Throughput capacity for for both methods

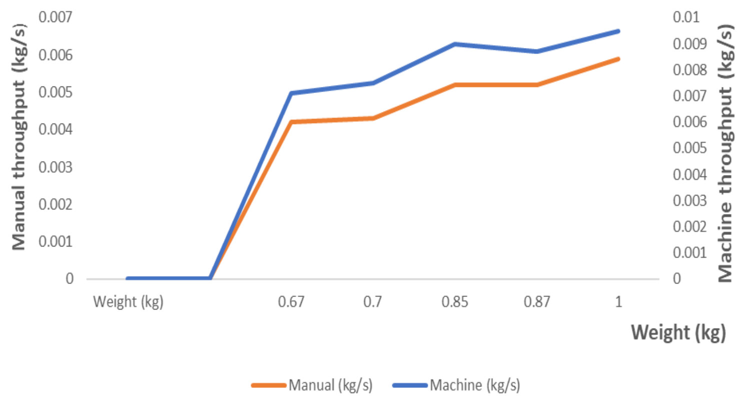

Figure 3: Effect of weight on de-husking time for both methods both methods

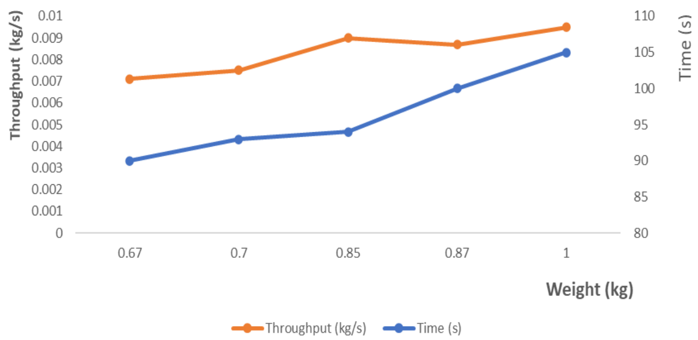

Figure 4: Relationship between throughput capacity, weight and time for the de-husking machine

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Table 2: Bill of engineering measurement and evaluation

S/N	Component/Material	COST (₦)
1.	Electrodes	3.000
2.	Steel material	13.000
3.	Transportation	2.000
4.	Pedal	1.000
5.	Seat	1.000
6.	Paint	2.000
7.	Labor	10.000
Total		**32.000**

The findings of this study contribute to the existing body of literature by highlighting the effectiveness of mechanized de-husking methods in improving processing efficiency. Despite the advancements in technology, there remains a notable gap in the availability of affordable and user-friendly machinery tailored to the needs of smallholder coconut farmers. Previous studies have indicated that many existing machines are either too complex or costly for widespread adoption among rural farmers (Santosa et al., 2019). This gap presents an opportunity for further research and development aimed at creating accessible solutions that can enhance the productivity and profitability of coconut farming.

Moreover, the implications of this research extend beyond mere efficiency improvements. The adoption of mechanized de-husking methods can lead to significant economic benefits for farmers by reducing labor costs and increasing the volume of processed coconuts. As highlighted by (Aliwarga, 2023), the integration of technology in coconut processing not only enhances productivity but also contributes to the overall sustainability of the coconut industry by minimizing waste and optimizing resource utilization.

In conclusion, the results of this study underscore the importance of mechanization in the coconut processing sector, particularly in enhancing efficiency and productivity. The significant differences observed between machine and manual de-husking methods highlight the potential for technology to transform traditional practices. However, addressing the existing gaps in affordable and user-friendly machinery remains a critical challenge that must be tackled to ensure that smallholder farmers can fully benefit from these advancements. Future research should focus on developing innovative solutions that are not only efficient but also accessible to the broader farming community, thereby promoting sustainable practices and improving livelihoods in coconut-producing regions.

CONCLUSION

This research successfully designed and fabricated a coconut de-husking machine, taking into account critical factors such as frame dimensions, blade strength, and spring tension. Performance tests conducted on the machine demonstrated its superior efficiency compared to traditional manual de-husking methods, as it consistently de-husked coconuts at a significantly faster rate. The implications of this research are substantial, offering coconut farmers a means to save time and reduce labor costs, thereby enhancing the overall productivity and sustainability of the coconut processing industry. Future research and development efforts should aim to further optimize the machine's design and investigate avenues for its widespread adoption among coconut-producing communities, ensuring that the benefits of mechanization are accessible to all stakeholders in the industry.

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