Design and Performance Assessment of a Mechanized Palm Fruit Stripper

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(Received: 07.05.2026; Accepted: 17.06.2026)

Abstract

Palm fruit stripping, a crucial step in palm oil production, remains a labor-intensive and time-consuming process, particularly for small-scale producers. Traditional manual stripping methods result in low efficiency, high labor costs, and significant post-harvest losses, hindering the overall productivity and profitability of palm oil production. The lack of efficient and reliable mechanized stripping technologies has contributed to these challenges, emphasizing the need for innovative solutions to improve stripping efficiency, reduce labor requirements, and enhance the quality of palm fruits for oil extraction. This paper presents the design, development, and performance evaluation of a mechanized palm fruit stripper, optimized for fruit density, size, and bunch compactness. The machine's key components, including the feed chute, stripping shaft, and chamber geometry, were designed based on empirical evaluations of palm fruit characteristics. Powered by a 2.23kW electric motor via a pulley system, the stripper achieved an average stripping efficiency of 98.91% and an output capacity of 0.0707kg/s. The machine's feed rate ranged from 341.4kg/hr to 360.02kg/hr, with a maximum output rate of 275.78kg/hr. Results demonstrate the stripper's potential for efficient and reliable palm fruit processing, addressing labor-intensive stripping challenges in small-scale palm oil production. The study's findings provide valuable insights for optimizing mechanized stripping technologies in palm fruit harvesting and processing.

Keywords: *Palm fruit; Mechanized; Efficiency; Reliability; Stripper; Design; Performance; Assessment*

INTRODUCTION

The oil palm (*Elaeis guineensis*) is a cornerstone of global palm oil production, playing a vital role in meeting the world's growing demand for vegetable oil. As one of the most widely cultivated crops in tropical regions, its cultivation and harvesting processes are crucial in determining the efficiency and quality of palm oil extracted from its fruit. The oil palm's significance in global agriculture and trade is immense, providing a versatile and cost-effective ingredient for various food and non-food products. In this context, the harvesting process is particularly important, as it has a direct impact on both the yield and quality of the final palm oil product (Enshasy *et al,* 2017).

According to Ologunagba *et al.* (2010), several mechanical approaches to palm fruit stripping have been developed, including rotary, vibrating, and centrifugal types. Rotary strippers, for instance, employ drums fitted with blades or spikes that rotate to detach fruits from bunches. The production cost of a dual-powered palm fruit stripper, excluding the electric motor, is estimated at about ₦18,350. Although such a price may be feasible for large-scale commercial producers, it represents a considerable expense for smallholder farmers. These financial constraints highlight the demand for simpler, more affordable machines that small-scale operators can readily adopt. The drive to create cost-effective and practical farm equipment has led to increased innovation tailored to the unique requirements of farmers across different regions. Daum *et al.* (2024) highlight that Africa's small-scale business owners have been central to building thriving markets for domestically manufactured farm equipment. This activity, in turn, bolsters rural economic growth and advances long-term sustainability.

Research was done to examine the design, construction, and performance testing of a palm fruit stripping machine created to improve the efficiency of palm oil processing. The equipment comprises a strong frame, a drum fitted with uniformly distributed stripping blades, a conveyor unit, and a power transmission system powered by an electric motor. The assembly process prioritized accuracy and safety through the inclusion of vibration dampers and protective features. Performance evaluations showed an efficiency range of 85–95% and a throughput of 200–300 kg/hr. The machine operates with optimized energy use and exhibits minimal wear during prolonged operation. Noise is kept below 85 dB, and vibration control measures improve operator comfort. With its emphasis on safety, dependability, and ease of operation, the stripper provides a feasible approach to sustainable palm fruit processing. This study supports the development of agricultural machinery by presenting a cost-effective and efficient option for small and medium-scale palm oil producers (Bankole *et. al.* 2025).

Fathima *et al.* (2023) detail the development of a manually operated implement engineered specifically for extracting pulp from toddy palm fruit. The device demonstrated a notable processing throughput of 9.01kg/h while keeping material losses to a minimal 2.4%, thereby highlighting how mechanical innovations can simultaneously enhance productivity and reduce waste. In addition, recent progress in automation has facilitated the creation of sophisticated systems capable of identifying fresh fruit bunches and detached fruitlets with precision levels reaching 99.2%. Beyond boosting operational efficiency, these automated technologies optimize the harvesting workflow by ensuring a greater proportion of fruit is collected at peak ripeness.

Saxena (2023) observes that constraints related to financing and regulation frequently impede the expansion of domestic manufacturing industries, thereby limiting smallholder farmers' ability to obtain the equipment necessary for enhancing agricultural productivity. Consequently, the implementation of supportive policies and strategic initiatives is critical for stimulating innovation and promoting the creation of agricultural machinery that is both cost-effective and easy to operate.

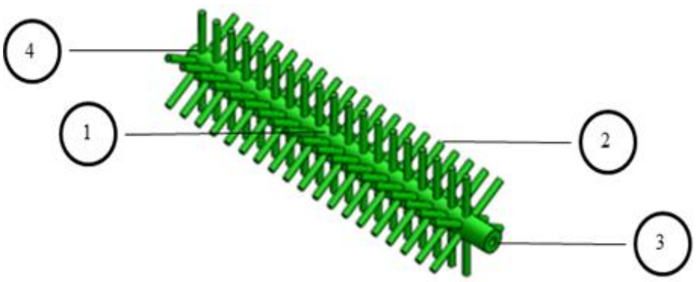
Yusuf *et al.* (2024) document the creation of a machine specifically engineered to process small palm fruit bunches (PFB), which recorded a stripping efficiency of 98.6% when operated at an optimal speed of 1000 rpm. Significantly, the equipment maintains fruit integrity, registering only 2.25% loss, thereby demonstrating both its operational efficiency and its viability for large-scale industrial application. Moreover, the design leverages centrifugal force as the primary separation mechanism, enabling effective detachment of mesocarp fibers from the nuts. This approach not only improves oil extraction rates but also reduces nut breakage. Consequently, overall oil yield is enhanced, positioning such machines as a critical asset within palm oil processing operations.

Moses *et al.* (2025) described the development of a palm fruit stripper engineered to prioritize high throughput, efficiency, and straightforward operation and maintenance. The design aims to minimize time losses and prevent acidity in palm fruits that results from fermentation. In their experimental procedure, palm fruit bunch samples were collected from eight different locations and heated at 100°C for 30-minute intervals. Each sample was then fed into the machine's hopper, and a stopwatch was used to measure the stripping duration. At a beater speed of 534.89rpm, the machine achieved its best performance with heating times of 30 and 240minutes, yielding an optimum efficiency of 98.8% and a clean fruit recovery rate of 94.8%. The stripper's capacity ranged from 18.75kg/s to 150kg/s, corresponding to stripping times of 80 seconds and 10 seconds, respectively. The overall efficiency of the machine was recorded at 97.4%. The study also found that heating influenced the size of the palm fruits during stripping. For instance, when 25 kg of palm fruit bunches were heated for 240 minutes, the stripping time was reduced to just 10 seconds. However, the prolonged heating increased fruit softness to the extent that the fruits were not only detached from the bunch but also separated from the kernels. This change in fruit texture affected the machine's processing performance during operation.

MATERIALS AND METHODS

This section describes the design considerations, material selection, and fabrication process of the mechanized palm oil stripper, as well as the experimental procedures and equipment used to evaluate its performance under different operating conditions.

Fig. 1 represents the isometric view of the spin shaft of a palm fruit stripping machine. It reveals a robust cylindrical shaft with 3-4 radially arranged beaters or paddles, strategically angled for optimal fruit stripping. The beaters are designed to



Item No.	Part Number	Quantuty
1	Shaft Body	1
2	Stripping Fingers	114
3	AFBMA 20.1 – 33-30-10,DE,AC.10_68	2
4	Drive Connection	1

S. No.	Materials for design and implementation of the palm fruit stripper	
1	Screws	(made of carbon steel)
2	Bearing	(made of chrome steel – 6204)
3	Shaft	(made of alloy steel – AISI 4140)
4	V-belt	
5	Painting materials	(consisting of clear coat, anti-rust, thinner, primer, and auto base paint)

Fig. 1: Isometric view of the spin shaft, and the materials and quantity of parts of the palm fruit stripper.

strike and dislodge palm fruits from bunches without causing excessive damage. Bearings at both ends of the shaft enable smooth rotation, allowing the machine to operate efficiently. As the shaft spins, centrifugal force helps in separating the fruits from the bunch. The spin shaft is a critical component in palm oil processing, contributing to the machine's overall efficiency. The design and construction of the spin shaft are crucial for effective palm fruit stripping and processing. Typically made from durable materials like steel, the shaft is designed to withstand the rigors of continuous operation. Its configuration ensures that palm fruits are stripped efficiently, making it a vital part of the palm oil extraction process.

Design Analysis

Physical and mechanical properties of oil palm fruits were considered in determining mesh size, power requirements, material selection, cost, and ease of operation.

Volume of Stripping Unit

Volume of striping unit (C_v) is computed by using the following formula:

$$C_v = \pi r^2 h \quad (1)$$

where:
r = radius of the stripping unit (m)
h = height of the stripping unit (m)

Gear Speed

Gear speed (N_g) is computed using the following relationship (Khurmi and Gupta, 2005):

$$N_g = \left(\frac{T_p}{T_g}\right) \times N_p \quad (2)$$

where:
T_g = number of teeth on gear
T_p = number of teeth on pinion
N_g = gear speed (rpm)
N_p = pinion speed (rpm)

Shaft Diameter

Shaft diameter is given by (Khurmi and Gupta, 2005):

$$d^3 = \left(\frac{16}{\pi S_s}\right) \times \sqrt{[(K_b \times M_b)^2 + (K_t \times M_t)^2]} \quad (3)$$

where:
d = shaft diameter (mm)
K_b = shock & fatigue factor (bending) = 1.5
K_t = shock & fatigue factor (torsion) = 1.5
M_b = maximum bending moment (Nm)
M_t = maximum torsional moment (Nm)
S_s = allowable shear stress = 450 N/mm²

Pulley Speed

Pulley speed is computed by the relationship provided by Onifade *et al.* (2016) and Adzimah and Seckley (2009), as given under:

$$N_1 \times D_1 = N_2 \times D_2 \quad (4)$$

where:
N_1 = driver pulley speed (rpm)
D_1 = driver pulley diameter (mm)
N_2 = driven pulley speed (rpm)
D_2 = driven pulley diameter (mm)

Centre Distance and Belt Length

Centre distance and belt length (Khurmi and Gupta, 2005) are computed as:

$$C = \frac{D_1 + D_2}{2} \quad (5)$$

$$L = \frac{\pi(D_1 + D_2)}{2} + 2C + \left(\frac{(D_2 - D_1)^2}{4C}\right) \quad (6)$$

where:
C = center distance (mm)
L = belt length (mm)

Belt Tension Ratio

Belt tension ratio (Khurmi and Gupta, 2005) is given by the following relationship:

$$\frac{T_1}{T_2} = e^{\mu\theta} \quad (7)$$

where:
T_1 = Tension in tight side (N)
T_2 = Tension in slack side (N)
μ = Coefficient of friction
θ = Angle of contact (rad)

Power Requirement

A change in speed of any fan in operation will predictably change the pressure rise and power necessary to operate under a predictable set of laws concerning its speed, power and pressure (Ojomo *et al.*, 2011). This law, when applied to agricultural equipment that uses a shaft as a power take-off, one of the equations from these laws is given as:

$$\frac{kW_1}{kW_2} = \left(\frac{N_1}{N_2}\right)^2 \quad (8)$$

where:
kW_1 = Power from the motor kW
kW_2 = Power required by the Gear shaft, kW
N_1 = Speed of the gear shaft (rpm)
N_2 = Speed of the motor (rpm)

Performance Assessment

The machine was installed on a level and hard surface. Sixty kilograms of freshly harvested palm fruit were purchased from a nearby farm, and 5kg of oil palm fruit bunch was prepared for the machine test. Each experiment was carried out in four replicates. The stripper was evaluated using the following formula;

i. Determination of feed rate (F_r)

Feed rate is the speed at which a fruit stripper processes the material, and is given by the formula:

$$F_r = \frac{Q_{bf}}{T_f} \quad (9)$$

where:
Q_{bf} = quantity of bunch feed provided.
T_f = time taken to feed.

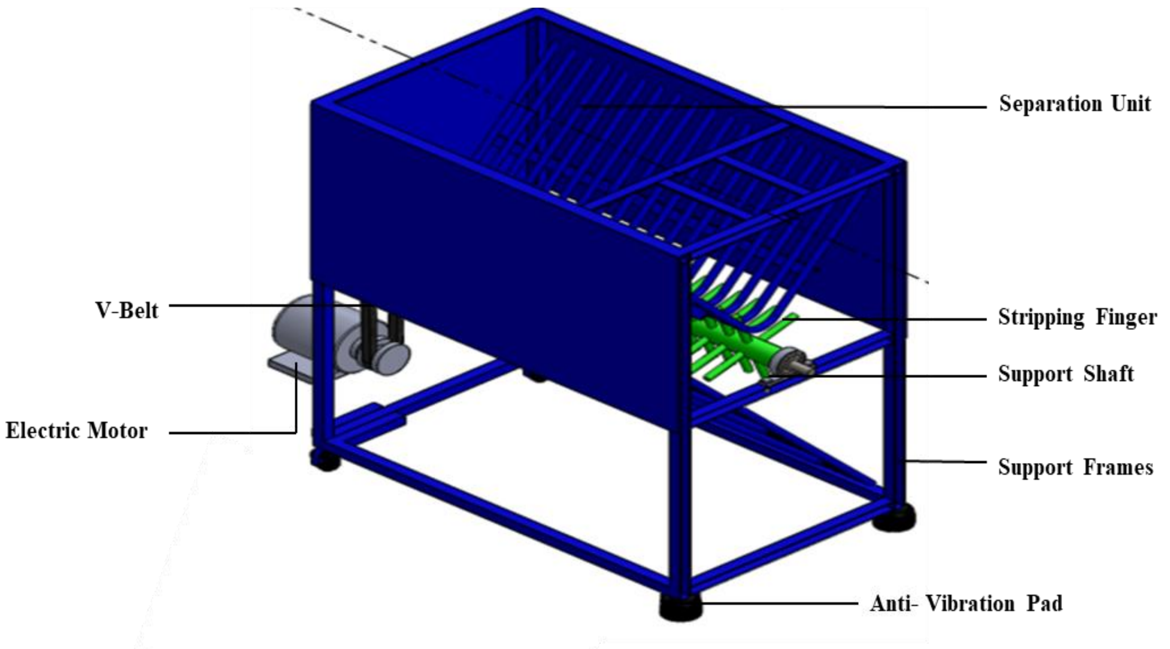


Fig. 2: Isometric view of the mechanized palm fruit stripper.

ii. *Determination of output capacity (Q_c)*

The output capacity of a palm fruit stripper is evaluated using the formula: ity = Weight of palm fruit stripped + (weight of empty bunch / Time of Stripping)

$$Q_c = \frac{W_{fs}+W_{eb}}{T_s} \quad (10)$$

where:
W_{fs} = weight of palm fruit stripped
W_{eb} = weight of empty fruit bunch
T_s = time of stripping

iii. *Determination of machine* efficiency (M_E)

The machine efficiency, in percentage, is computed by using the formula:

$$M_E\ (\%) = \frac{W_{fs}}{W_{ft}} \times 100 \quad (11)$$

where:
W_{fs} = weight of palm fruit stripped
W_{ft} = total weight of fruit in the bunch prepared for stripping

iv. *Determination of quality performance efficiency (Q_{PE})*

The Quality performance efficiency, in percentage, is computed by using the formula:

$$Q_{PE}\ (\%) = \frac{W_{fs}}{W_{eb}+W_{fu}} \times 100 \quad (12)$$

where:
W_{fs} = weight of palm fruit stripped
W_{eb} = weight of empty fruit bunch
W_{fu} = weight of fruit unstripped

RESULTS AND DISCUSSION

This section presents the performance evaluation of the designed mechanized palm oil stripper. The results obtained from test runs at varying operating conditions show the machine's stripping efficiency, throughput capacity, and energy utilization.

Fig. 2 is the isometric view of the mechanized palm fruit stripper showing a compact, sturdy machine in a 3D angled perspective. It features a cylindrical stripping drum mounted on a rectangular mild steel frame. At the top is a hinged feeding inlet for loading palm fruit bunches. Inside the unit is a rotary system with beaters or rods that detach the fruits.

The 2.23kW electric motor is mounted at the base/side, connected via belt drive to the shaft. Below the shaft is a perforated screen for fruit separation, with a discharge outlet for stripped fruits and an off-load tray for empty bunches/spikelets. The overall design is robust, elevated on a stable base frame for easy operation and maintenance.

CONCLUSION

In conclusion, the design and performance assessment of the mechanized palm fruit stripper successfully fulfil its primary objective of transforming the traditionally labor-intensive and inefficient process of palm fruit bunch stripping into a reliable, high-throughput mechanical operation. Powered by a compact 2.23 kW electric motor, the machine consistently delivered an average stripping efficiency of 98.91%, effectively detaching fruits from the bunches with minimal residual attachment and negligible fruit damage. This exceptional efficiency not only exceeds conventional manual stripping methods, which are often limited by worker fatigue and inconsistent output—but also ensures that the integrity of the mesocarp is preserved for optimal downstream oil extraction.

The machine's output capacity of 0.707 kg/s further underscores its practical superiority, translating into a maximum throughput rate of 275.78 kg/hr under continuous operation. Such productivity levels enable small- to medium-scale palm processors to significantly reduce processing time, lower labor costs, and increase overall yield per unit time, thereby enhancing economic viability in palm oil-dependent regions. Field evaluations confirmed stable torque transmission, smooth rotational dynamics, and low energy consumption, validating the robustness of the selected components and the ergonomic frame design.

Beyond technical performance, the mechanized stripper addresses critical socio-economic challenges by alleviating drudgery, minimizing occupational hazards, and promoting inclusive participation in palm fruit processing. Its affordability, ease of maintenance, and adaptability to varying bunch sizes position it as a sustainable innovation that aligns with the goals of agricultural mechanization and food security. While the current prototype has proven highly effective, future refinements could incorporate variable-speed controls, sensor-based automation, and hybrid power options to further expand its applicability across diverse farm scales. Ultimately, this mechanized palm fruit stripper represents a pivotal advancement that bridges traditional practices with modern engineering, paving the way for enhanced productivity, profitability, and sustainability in the global palm oil value chain.

Grant Support Details

This research was not supported by any grants from funding bodies in the public or private sectors.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy, have been completely observed by the authors.

Grant Support Details

The present research did not receive any financial support to conduct the research.

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