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Development of Motorized Groundnut Pod Picker

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ABSTRACT

Groundnut holds a prominent place in Nigeria's agricultural landscape, offering a versatile array of applications, from animal feed to edible oil and industrial uses. However, the traditional practice of hand-picking groundnut pods has posed a significant challenge for farmers, consuming time, and energy. In response to these obstacles, a ground nut pod stripper was designed, fabricated, and tested. The machine comprises of feeding tray, a picking drum equipped with spikes, a concave chamber, pods exit, and a sturdy frame. Its design is simple and easy to maintain, ensuring that it can be used effectively by a wide range of farmers. The equipment can be powered with an electric motor or a gasoline engine and is portable for easy movement. Its performance was evaluated using ground nut plants with pods to determine its throughput capacity and operating efficiency to be 146 kg/hr. and 97,6%, respectively. The overall cost of fabrication was ₦102,620 making it an accessible and cost-effective solution for ordinary Nigerian farmers. This affordability ensures that the benefits of the machine are not limited to large-scale agricultural enterprises but can be harnessed by small-scale and subsistence farmers as well.

1. INTRODUCTION

Groundnut (*Arachis hypogaea L*.) is a leguminous plant that is commonly cultivated on an annual basis. It is renowned for its high-oil edible seeds, making it the fourth-largest source of edible oil and the third-largest source of vegetable protein globally. This versatile crop is a key ingredient in numerous sweets, snacks, and breakfast items, and it is also used in the preparation of various culinary delights. Groundnut plays a pivotal role in international agricultural trade, with significant exports to various parts of the world. The global cultivation of ground nut covers an extensive 295 million hectares, yielding an impressive 487 million tonnes, with an average yield of 1647 kg per hectare (Anant *et al.*, 2023).

Despite its economic importance groundnut cultivation faces a significant challenge in the form of stripping the seeds from the plant. Farmers typically resort to labor-intensive methods, (Plate 1) such as hand-plucking or using rods to dislodge the nuts. However, these methods are time-consuming and yield insufficient output, failing to meet the market's ever-growing demand (Anant *et al*., 2023).

Ground nut seeds consist of approximately equal weights of fatty and non-fatty oils, the exact proportions of which vary depending on the variety and maturity of the nut. On average, groundnut seeds contain between 42% to 52% oil. Extracting this oil is a straight-forward process, typically achieved by crushing the seeds. The resulting oil is highly prized for its health benefits and culinary applications. The oil derived from groundnuts is notable for its high content of unsaturated fatty acids, such as oleic and linoleic acids. After extracting oil from groundnut seeds, what remains is known as groundnut cake. This cake is a protein-rich byproduct with concentrated proteins, minerals, and vitamins. It can be used as animal feed, providing a valuable source of nutrition for livestock (Mohammed and Hassan, 2012).

One of the most remarkable aspects of the ground nut plant is that almost no part goes to waste. Beyond the seeds and cake, the entire plant has valuable applications. The leaves and stems are rich in nutrients and can serve as a nutritious dietary component for various livestock, making it an eco-friendly and cost-effective feed source. Alternatively, the plant can be dried and used as mulch or compost, enriching the soil with valuable organic matter. When burned, the plant material turns into ash, which can be used as a natural fertilizer, enhancing soil fertility and crop growth (Mohammed and Hassan, 2012).

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Anant *et al*., (2023) introduced a pod stripper with dimensions of 1170 × 930 × 560 mm. The performance evaluation of this newly developed pod stripper was tested under varying conditions of three key variables: moisture content (% db), feed rate (kg/h), and cylinder speed (m/min). The study focused on assessing the impacts of these variables on the dependent factors, namely stripping efficiency, cleaning efficiency, and damage percentage. The results of the experimentation revealed the stripping efficiency of the pod stripper to be 87%, showcasing its effectiveness in separating pods. Additionally, the stripping capacity was measured at 195 kg/h, indicating the machine's capability to efficiently process and strip pods at a significant rate. While groundnut remains a vital crop in the global agricultural landscape, the challenge of seed stripping threatens its sustainability. Addressing this issue is imperative to ensure that groundnut cultivation remains profitable and continues to meet the growing demand for its high-oil seeds and versatile applications. There is need to develop mechanized stripping machine, hold promise for a more efficient and productive groundnut industry. By conquering the stripping challenge, groundnut farming can thrive and contribute to global food security and economic development.



Plate 1: Picking the groundnut pods using the Hand method.

2. METHODOLOGY

2.1 Design Considerations

In other to ensure improve machine performance, high level of functionality and better durability, these factors were considered in the design of motorized groundnut pod picker: ease of operation**,** cost effective, less maintenance and repair of the design machine, availability of materials locally, ergonomic of operation, less weight and engineering properties of groundnut.

2.2 Material Selection

The selection of materials for this project was based on strength, availability, durability, and resistance to corrosion. Additionally, factors such as ease of construction and maintenance were taken into account to prevent potential machine damage. In constructing the frame, mild steel angle iron was chosen for its robustness. Similarly, mild steel metal sheet was employed in fabricating the picking chamber and various other components. It is worth noting that all the materials utilized in this project were procured from a local market, underscoring a commitment to accessibility and local sourcing.

2.3 Major Machine Components

The groundnut pods picking machine is designed to be made up of the following major parts:

2.3.1 The Frame

This is the actual part of the machine that hold, support all the working parts of the machine, and is made of rigid mild steel angle iron. Figure 2 presented the designed frame and the engine seat.

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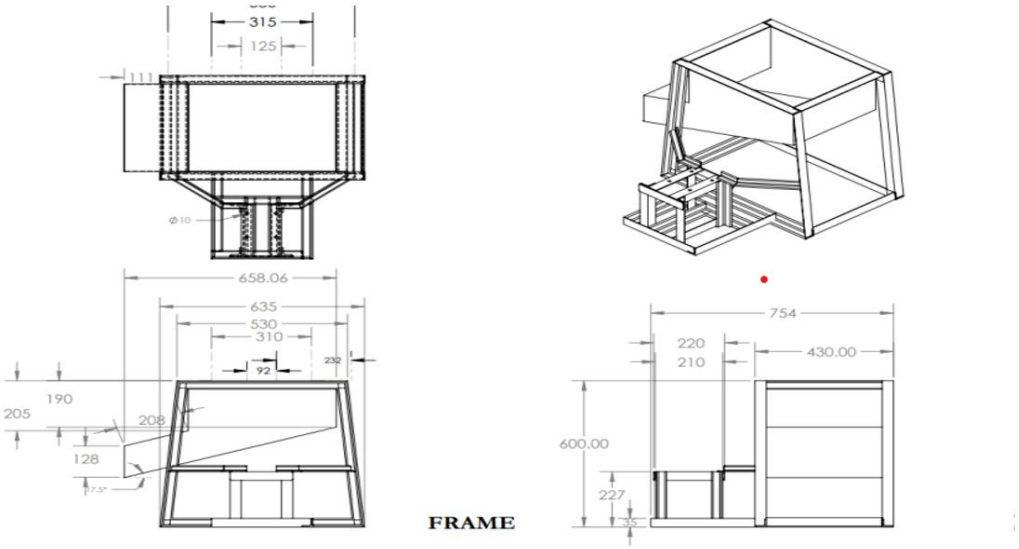


Figure 2: Machine frame and Engine seat

2.3.2 Feeding Tray

This is the part where the groundnut panicles are being fed into the picking drum. It is made of mild steel material. Figure 3 presented the designed feeding tray for the fabricated machine.

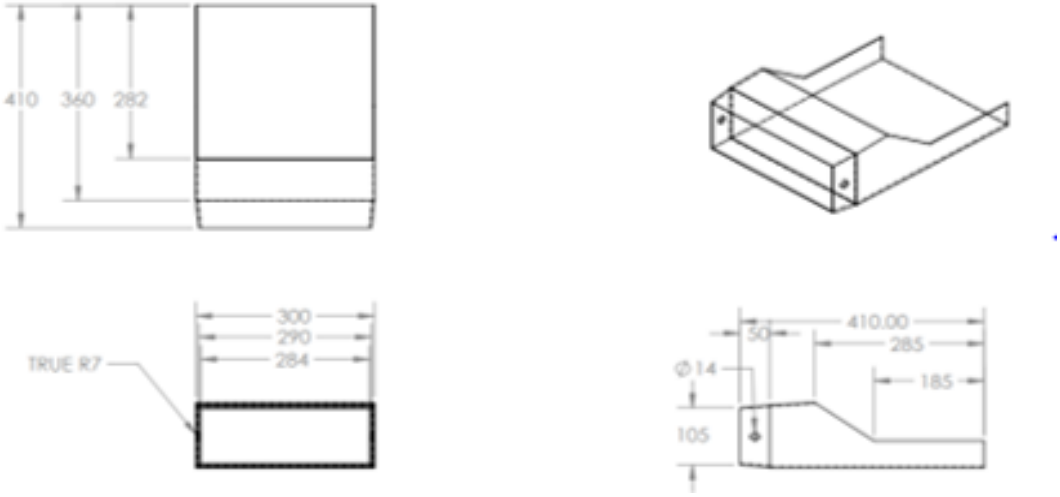


Figure 3: Feeding Tray

2.3.3 Pods Picking drum (Toothed Drum)

The stripping drum is one of the main parts of the developed machine. The machine drum perform major tasks of removing the pods from the plant using impact and frictional forces and made of mild steel material which also housed the picking chamber. Figure 4 showed the designed pods picking drum for the stripping pod machine.

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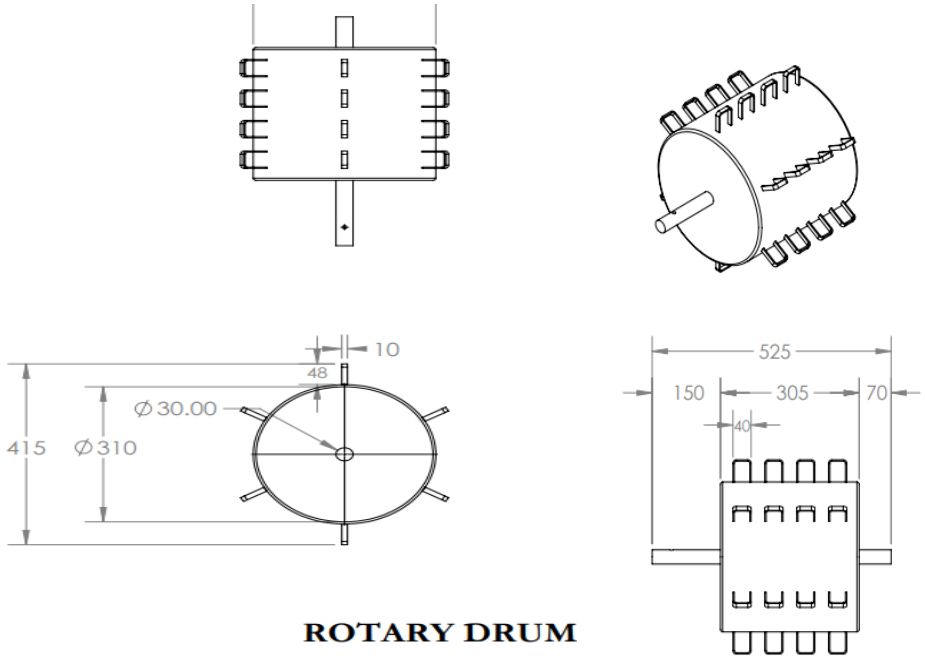


Figure 4: Pods Picking drum.

2.3.4 Machine Pulley

For effective power transmission from the prime mover to the designed machine, pulleys are required for both machine and prime mover. Figure 5 presented the designed pulley.

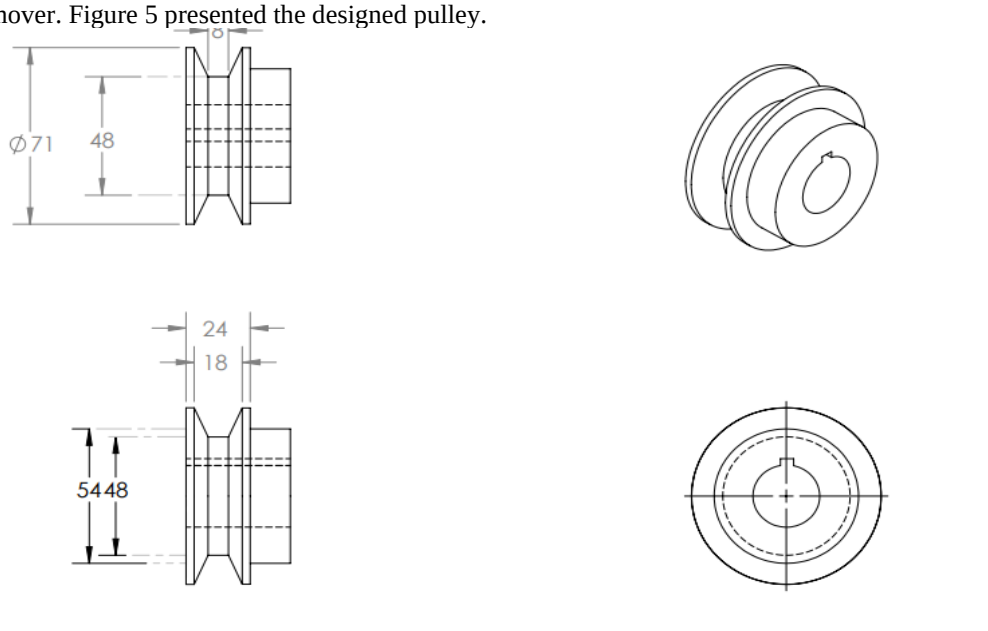


Figure 5: Driving pulley.

2.3.5 Discharge outlet

The machine consists of a single outlet opening in the front of the machine for allowing exit of the pods.

2.5 Machine Description

The main component of the machine consists of a frame, feeding tray, prime mover seat, pod picking drum, shaft, bearings, pulleys, and discharge outlet. The frame was made of angle iron and the engine seat was manufactured from the same material. It was designed to hold the engine firmly with proper balance and stability during machine operation. Figure 6 shown the prototype of designed machine.

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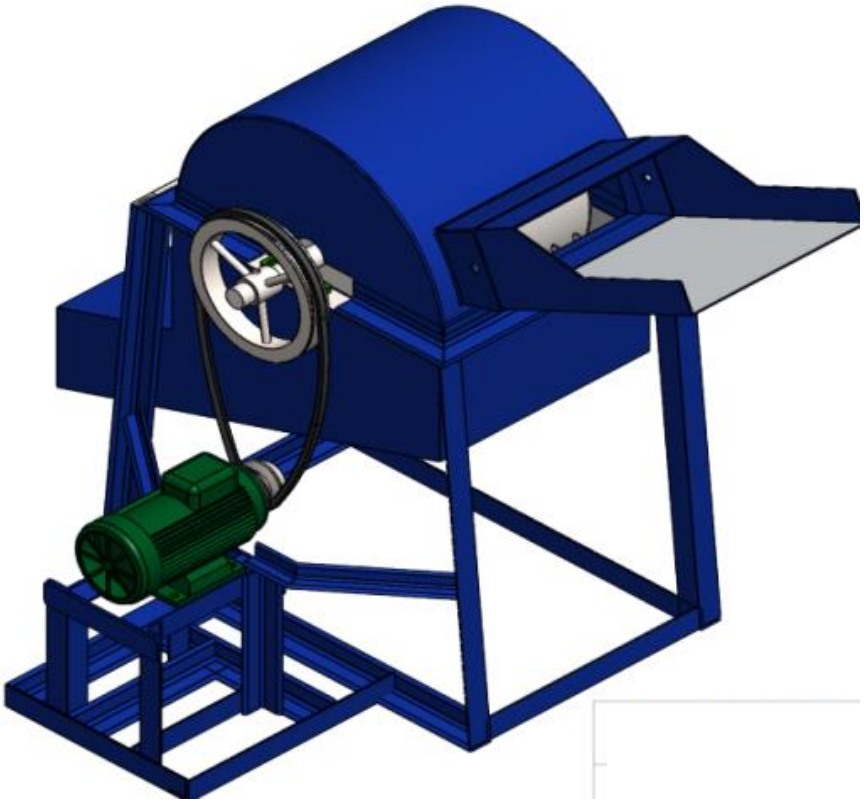


Figure 6: Designed Motorized Groundnut Pod Picker.

2.6 Design Analysis

2.6.1 Determination of Picker Drum Capacity

This is the unit where the groundnut pods are beaten out of the straw. It is made of mild steel and consists of a rotary drum with beater pegs and a stationary concave grid. The picking drum speed (equation 1) and its capacity (equation. 2) were adopted from Daniyan *et al.*, (2014).

$$V = d \times \pi \quad (1)$$

Drum capacity (kg/sec) is given as

$$D = 3.6 \times A \times \rho \times V \quad (2)$$

Where:
D = drum capacity (kg/m)
V = Belt speed (m/s)
A = Belt sectional area (m^2)
d = Roller diameter
ρ = Material density (kg/m^3)

2.6.2 Determination of Stripping Rim Diameter

The diameter of stripping cylinder was determined using relationship in equation (3) as reported by Anant *et al.*, 2023.

$$D_v = \frac{C_{pv}}{\pi \times N_c} \quad (3)$$

Where:
D_c = Diameter of rim, m;
C_{pv} = Peripheral velocity of cylinder, m/s;
N_c = Speed of cylinder, rpm.

2.6.3 Determination of Length of Stripping Cylinder

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Drum Length of stripper is determined by using Winkler formula as reported by Anant *et al.*, (2023) and express in equation (5)

$$L_d = \frac{F_r \times (1-\delta)}{0.25 \times N \times n \times k} \quad (4)$$

Where:
L_d= Drum length
Fr = Stripper feed rate, kg/s;
n = Number of rims on stripping cylinder.
N = Speed of stripping drum /s;
k = range from 0.17 to 0.32 kg per length of the drum.
$\delta' = 1/\delta$; and
δ = Straw grain ratio.

2.6.4 Determination of Pulley Dimension

To determine peripheral speed the following relationship (equation 5 and 6) were used as reported by Davies (2009).

$$N_1 D_1 = N_2 D_2 \quad (5)$$

Where:
D_1 = Diameter of the drive pulley, mm; D_2 = Diameter of the driven pulley, mm.
N_1 = Speed of the drive pulley, rpm; and N_2 = Speed of the driven pulley, rpm.
To determine the value of N_2 using relationship in equation 6 as reported by Anant et al. (2023)

$$N_2 = \frac{V}{\pi D} \quad (6)$$

Where:
V = Velocity required for stripping of groundnut, m/s
D = Diameter of stripping cylinder, mm

2.6.5 Determination of Length of Belt

Length of open belt was determined using relationship in equation (7)

$$L = \frac{\pi}{2}(D + d) + 2C + \frac{(D+D)^2}{4C} \quad (7)$$

Where:
C = Different between the drive and driven pulley, mm.
D = Drive pulley diameter, mm; and
d = Driven pulley diameter, mm.

2.6.6 Machine Torque

According to research carried out by Rajasekar *et al.* (2017), the force or the tensile force required to separate peg from ground nut pod is 22.26 N. Assuming 5 to 10 ground nut plants /bunches for each batch operation, so the maximum force required to remove groundnut pod from the ten bunches will be 223 N, considering the weight of shaft and other mountings components. The force was assumed to be 300 N while torque the was determined from the relationship in Equation (8)

$$T = F \times d \quad (8)$$

Where:
T = Torque, Nm
F = Force, N
d = Perpendicular distance, mm
Perpendicular distance is the clearance between the shaft axis and the plate edge which is 120 mm.

2.6.7 The Power Transmission unit

According to a study carried out by Abady *et al*. (2019), the tensile force required to remove a peg from a pod is 22.26 N. The force needed to extract the groundnut pod in this situation, considering the weight of the shaft, drum weight and picking devices was assumed to be up to 100 N as many groundnut plants may be processed at the same times. Power required was calculated using relationship in equation (9).

$$P = \frac{2\pi NT}{60} \quad (9)$$

P = Power required to drive the machine, w
N = Speed of machine, rpm
T = Machine torque, Nm
Taking factor of safety of 1.5 times

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2.7 Working Principle of the Machine

A 1.5 Hp petrol engine was used to delivers rotational energy via a pulley and belt system to the shaft of the picker drum, causing the spiked drum (cylinder) to rotate. As groundnut panicles were introduced into the picking drum via the feeding tray, the groundnut pods are separated from the straw. This separation is achieved by a rotating cylinder equipped with beater pegs, situated above a stationary grid referred to as a concave. The separated pods, then gathered from the outlet.

2.8 Performance evaluation of the designed groundnut stripper

After the designed analysis of the machine concept, the machine was fabricated, and its performance was evaluated on the following parameters:

2.8.1 Stripping rate (SR)

The rate at which groundnut pods separated from the plant per unit time. It was calculated using relationship in equation (10) as reported by Nur (2023).

$$SR = \frac{WS}{ST} \quad (10)$$

Where,

SR - Stripping rate (kg hr^{-1}),

WS - Weight of pod stripped(kg) and

ST – Time taken to strip the pod (hr.)

2.8.2 Percentage of unstripped pods

The rate at which groundnut pods undetached from the plant per unit time and expressed in equation (11) as reported by Ghatge *et al.*, (2014).

$$PUP = \frac{WUP}{TWP} \quad (11)$$

Where:

PUSP - Percentage of unstripped pods,

WUSP - Weight of unstripped pods (kg) and

TWP - Total weight of pods (kg)

2.8.3 Stripping efficiency (SE)

The efficiency was calculated using relationship in equation (12) as reported by Nur (2023).

$$SE = \frac{WSP-LOSS}{TWP} \times 100 \quad (12)$$

Where:

SE - Stripping efficiency (%),

WSP - Weight of stripped pod (kg) and

TWS - Total weight of pod (kg)

2.9 Experimental procedure

The performance evaluation of the machine was conducted using two variables (moisture contents and picker speed); the three levels of picker speed (250 rpm, 500 rpm and 750 rpm) and two levels of moisture content (moisture content of immediately harvested ground nut plant from the field with average moisture content of 50% in wet basis and dried for 5 consecutive days with sun and the average moisture contents reduced to 16%). A total of 6 experiments were formulated with three replications in order to determine the picker speed and moisture content that gives the optimum performance of the designed machine (Table 1). Moisture content was determined using KT100S moisture meter. Performance evaluation was carried out following the existing literatures and research work of Nur (2023).

Table 1: Combination of experimental treatments

S/N	Treatment	Coded	Actual
1.	T_1	W × S_i	Wet with speed of 250 rpm
2.	T_2	W × S_{ii}	Wet with speed of 500 rpm
3.	T_3	W × S_{iii}	Wet with speed of 750 rpm
4.	T_4	D × S_i	Dry with speed of 250 rpm)
5.	T_5	D × S_{ii}	Dry with speed of 500 rpm)
6.	T_6	D × S_{iii}	Dry with speed of 750 rpm)

3. RESULTS AND DISCUSSION

All data obtained were subjected to analysis of variance (ANOVA) appropriate for randomized complete block design (RCBD).

3.1 Stripping rate

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The results of the analysis of variance (ANOVA) revealed (Table 2) a significant impact of both operating speed and moisture levels on the stripping rate of the machine. The highest and lowest mean stripping rates were observed in treatment D × S_i (146.4 kg hr-1) and W × S_{iii} (124.5 kg hr-1), respectively (refer to Table 3). Specifically, the average stripping rate at the moisture level immediately after harvest, coupled with a drum speed of 750 rpm, was 85% lower than the rate achieved through drying with a drum speed of S_{iii} (250 rpm), maintaining the same average feeding rate of 135.3 kg hr-1 (see Table 2). This discrepancy indicates that the treatment dried for 5 days and stripped with a drum speed of 250, 500, and 750 rpm showed a 7.58%, 5.89%, and 3.89% increase, respectively, compared to the moist treatment (stripped immediately after harvest) at the same operating speeds. This is implied, the fresh stripping take more time than dry stripping. This discovery is consistent with Nur's (2023) research, which revealed an increase in percentage of pod stripping as drum speed increased within the speed range of 200 to 600 rpm. He also emphasized the significant impact of operating speed and moisture content on the efficiency of mechanical pod stripping. Furthermore, Ghatge *et al.*, (2014) observed that most groundnut plants that sun dried in the fields for 4 to 5 days before the stripping process. This pre-drying method was found to yield relatively high efficiency in pod stripping with stripping rate of 62 kg per person per hour over an 8-hour working day, translating to 7.75 kg hr^{-1}. Consequently, average stripping rate per hour of dried groundnut pod stripped with designed machine was 17.5 times higher than traditional hand stripping method.

Table 2: Analysis of Variance (ANOVA) showing effect of operating speed and moisture levels

Wet	**Speed**	***F***	***P-value***	***F crit***
	250	10178.22	p<0.05	4.41
	500	277826.42	p<0.05	4.41
	750	2843998.39	p<0.05	4.41
Dry	**Speed**	***F***	***P-value***	***F crit***
	250	8042.72	p<0.05	4.41
	500	388239.76	p<0.05	4.41
	750	1997773.02	p<0.05	4.41

Table 3: Interaction Effect of Moisture content and Operating Speed on Stripping Efficiency

S/N	**Treatment**	**WSP (kg)**	**WUSP (kg)**	**SR (kg hr^{-1})**	**SE (%)**
1.	W × S_i	4.51	0.49	135.3	90.2
2.	W × S_{ii}	4.47	0.53	134.1	89.4
3.	W × S_{iii}	4.15	0.85	124.5	83.0
4.	D × S_i	4.88	0.12	146.4	97.6
5.	D × S_{ii}	4.75	0.25	142.5	95.0
6.	D × S_{iii}	4.30	0.70	129.0	86.0

3.2 Stripping efficiency

The operational parameters of a machine, namely moisture content and stripping drum speed were identified as key factors influencing stripping efficiency. The analysis of variance (ANOVA) revealed a significant impact of drum speed on machine stripping efficiency (P<0.05), while moisture level did not exhibit a statistically significant effect on the same (see Table 2). The highest mean stripping efficiency of 97.6% was achieved through dry stripping with a drum speed of (250 rpm) for treatment D × S_i whereas the lowest efficiency of 83.0% was observed in wet stripping with a drum speed of 750 rpm (refer to Table 3). The findings suggest that an increase in operating speed correlates with a reduction in stripping efficiency and an increase in pod loss. The recent findings align closely with the outcomes reported by Simonyan and Oni (2001), who observed an increasing trend in both threshing efficiency and extractor efficiency as moisture content decreased. They particularly highlighted the significant impact of cylinder speed on the overall effectiveness of threshing processes. In contrast, the current results diverge from the research conducted by Afify *et al.* (2007), they reported that increasing feed rate from 600 to 900 kg hr^{-1} at constant drum speed of 6.28 m s^{-1} and seed moisture content of 13.63%, decreased the stripping efficiency by 0.97%.

3.3 Bill of Engineering Measurement and Evaluation of ground nut pod picker

The materials used for construction of designed ground nut pod picker were listed in Table 4 with their unit price.

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Table 4: The bill of materials for the designed ground nut pod picker

S/No	Material	Specification	Quantity	Unit Price (₦)	Amount (₦)
1	Steel sheet	2 mm thick	1	10,000	10,000
2	Mild steel angle iron	2 mm x 2mm	1.5	5,000	7,500
3	Mild steel shaft	525 mm x 25 mm dia.	1	4,000	4000
4	Pod piking drum				
	(a) central shaft:	525mm x 25mm dia.	1 length	4,000	4,000
	(b) picking spikes (mild steel flat bar:	-	1 length	2,500	2,500
	(c) Mild steel sheet:		1 sheet	5,000	5,000
5	Ball roller bearings	25mm bore	2	1,300	2,600
6	Driving belt	A38	1	200	200
7	Electrodes	Gauge 12	1 park	2,700	2,700
8	Cutting disc		2	1,000	2,000
9	Grinding disc		1	7,000	7,000
10	Paint (black)	Black			5,000
11	Bolt and Nuts	17mm	2	50	100
		13mm	4	30	120
12	Petrol Engine	1Hp	1	46,900	47,400
13	Transportation				5,000
	Total				**102,620**

4. CONCLUSION

The designed machine was tested for optimal performance, transforming the way small-scale farmers operate by drastically improving stripping efficiency and reducing both time and cost of stripping. It eliminates the need for a greater number of workers, replacing manual labor with a single operator. The impressive performance metrics achieved a stripping efficiency of 97.6%, ensuring that almost every pod was effectively separated from the plant. The machine's stripping capacity was equally remarkable, with the ability to process 146 kg of groundnut pods per hour. The total cost of the developed machine was ₦102,620.00 which is affordable and quickly offset by the savings in labor and the increased output. In fact, the machine is 20 times more productive than the manual method, making it a sound investment for small-scale farmers. The developed machine will play a crucial role in driving progress and ensuring a prosperous future for ground nut farmers.

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