

Comparative Evaluation of Human-Assisted and Semi-Automated Peeling Systems for Roasted Groundnut Seeds

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Abstract. This paper investigates human-assisted and semi-automated peeling systems for roasted-seed groundnut peeling machines, highlighting recent technological advances. The machine is designed to reduce manual labour, minimise fatigue, and save time during peeling. Powered by electricity, the machine includes components such as a feed hopper, a shaft, a frame, a variable-speed electric motor, a universal joint coupling, and a peeling brush. Performance evaluations were carried out to assess the machine's efficiency. Results showed a strong, significant correlation ($r=0.828$), indicating an 82.8% relationship among the tested parameters, providing the best fit. The machine's performance varied with different revolutions per minute. While hand peeling 5 kg of groundnuts takes about 3-5 hours, the machine completes the task in just 14 minutes. It achieves a peeling efficiency of 90%, a broken nut percentage of 11%, and a capacity of 19.6 kg/h of peeled groundnuts.

Keywords: Design and fabrication; Rotary peeling system; peeling efficiency; Mechanical processing of groundnuts; groundnut peeling machine.

INTRODUCTION

Roasted groundnut seeds are relevant because they provide essential nutrients for human consumption and serve as critical raw materials for industrial food processing and value-added agro-economic activities. Advancement: Scholars often describe this technology as improving the efficiency with which humans exploit their physical environment to meet their needs. Such technological progress enables productivity to grow faster than the population. The discovery of petroleum in the country led to the abandonment of many agricultural products, including groundnuts. This shift actually impacts the economy because a larger portion of the country's population depends on farming for their livelihood. Groundnut has the highest oil content of all food crops and is second only to soybean in protein content (20-30%) among food legumes [1]. As a legume, it plays a vital role in feeding both humans and animals, especially in developing countries, where it meets up to two-thirds of

human nutritional needs. Moreover, because they can fix nitrogen from the air, they do not require much chemical fertiliser, making them a better option for poor farmers who cannot afford fertiliser and a lucrative opportunity for wealthier farmers [2].

A wide variety of food products are made from groundnuts, including boiled nuts, roasted nuts, salted nuts, groundnut milk, groundnut yoghurt, groundnut bars, groundnut butter, groundnut cheese, and bakery items, among others [3]. In Nigeria, groundnuts are processed into finished products for human consumption, with various local preparation methods practised across different regions and ethnic groups. Some of these recipes and uses are not documented in writing but are passed down orally from one generation to the next, meaning they may disappear as the knowledge holders pass away. Groundnut is one of the most popular commercial crops in Nigeria; the country accounts for 41% of West Africa's total groundnut output [4]. In Nigeria, the processing of groundnuts into various products is

mainly undertaken by women, either for household use or commercial purposes [5]. The most common commercial groundnut products are groundnut oil, groundnut cake, and fried groundnuts, which are sold at markets or hawked on the streets [6].

This research aims to develop a machine that performs a range of Human-Assisted and Semi-Automated Peeling Systems for Roasted Groundnut Seeds, thereby reducing human effort and improving productivity. The research focused on developing a more efficient method for peeling roasted groundnut seeds. The machine, built by modifying an existing model, was constructed and tested. It has two chambers: one for peeling and another for blowing. The machine operates continuously, with both chambers operating simultaneously.

Raw groundnuts are consumed worldwide. Authors [7] noted that roasted groundnuts are heated to 180 °C for 12–15 minutes and cooled to 35°C –40 °C for 10–20 minutes when cooled with forced air or a blower. Authors [8] developed a portable, electrically powered dry groundnut husk peeling machine using a 1 H.P. motor to address the limitations of traditional manual peeling. The use of locally sourced materials made it cost-effective and easy to maintain. Performance testing showed a peeling efficiency of 92.14% and a capacity of 36.12 kg/hr, compared to manual peeling at 4.2 kg/hr per person with a split husk rate of 35%. This machine enhances productivity and efficiency, benefiting small- and medium-scale farmers.

Authors [9] developed an electric machine for peeling roasted bold peanuts, which account for 60% to 70% of consumption due to their higher compressive strength and sweeter flavour. These peanuts range from 14 mm to 18.4 mm in length and 9 mm to 10.6 mm in diameter, with an average roasted compressive strength of 308 g/cm². For optimal peeling, they should be sand roasted at 150 °C to 160 °C for 45 to 60 seconds. The machine processes an average of 5.042 kg of roasted peanuts, yielding 3.989 kg of peeled peanuts, 0.605 kg of unpeeled peanuts, and 0.448 kg of broken peanuts, achieving an efficiency of 79.129% and a capacity of 75 kg per hour, making it valuable to the food industry. Authors [9] investigated the performance parameters and physical properties of blowers. Despite their usefulness, blowers often experience vibration, poor performance, excessive noise, and

premature failure, which can limit operational speed. Engineers added appropriate ball bearings to enhance noise reduction and tackle these problems. Authors [10] developed a manually operated de-sinning and winnowing machine. The main component of the machine is the polishing chamber, which consists of the rough surface plate and the scrubber. The groundnut seed passes through a space called polishing clearance, located between the rough surface plate and the scrubber. The machine requires 0.34 kW of power, has a throughput capacity of 27.47 kg/hr, and has an efficiency of 53%. Authors [11] developed a groundnut peeling machine with a capacity of up to 25 kg/hour, powered by an efficient ¼ H.P. (185 W) electric motor. It features a rotary system with multiple discs that minimises damage to groundnut husks to below 5%, ensuring that more than 95% of the peeling remains intact.

Based on literature searches conducted so far, various types of peeling machines have been developed to address issues associated with manual methods. However, these issues include time wastage, high labour costs, inadequate collection techniques, groundnut peels falling into the bowl from a height and breaking into multiple pieces, and the need for manual operator intervention. Therefore, there is a demand for improved solutions. Consequently, a comparative analysis of human-assisted operated and semi-automated roasted seed groundnut peeling machines that require minimal human effort is necessary.

METHOD

This study offers a comparative analysis of human-assisted and semi-automated peeling systems for roasted-seed groundnut peeling machines. It looks at various components, such as the feed hopper, shaft, frame, variable-speed electric motor, universal joint coupling, and peeling brush. The design team used standard values to develop the design and specifications and selected fasteners and arc welding for their weld strength, durability, ease of operation, and cost-effectiveness.

The materials selected for fabrication were chosen after careful study and thoroughly assessed based on their physical, mechanical, chemical, and aesthetic properties, as detailed in Table 1. For this project, given economic factors and material availability, high- and medium-

carbon steels were primarily used, with stainless steel used for the body parts.

Table 1 – Selections of Materials

Machine components	Criteria for selection	Most suitable material	Material actually selected	Reason for selection	Limitations of selected material
Hopper	Smooth	Stainless steel	Stainless steel	Does not react with feeds. Light, easily fabricated, weldable, and resistant to corrosion.	It is expensive
Frame	1. Tensile strength 2. Malleability	Mild steel	Mild steel	It has good resistance to shock and wear	It is not expensive
Peeling and blower chamber	Smooth	Stainless steel	Stainless steel	And does not react with groundnut	It is expensive
Shaft	Smooth and ductile	Stainless steel	Stainless steel	It has high resistance to wear and resistance to distortion, and does not react with groundnut.	It is expensive.
Bearing	To support the shaft	Cast iron	Cast iron	It runs smoothly	It is expensive
Electric motor	To run the machine	Cast iron in winding steel	Cast iron in winding steel		
Bolts and nuts	Link fastener	Mild steel	Mild steel	Does not react with groundnut	It is not expensive

Design of Peeling Chamber

1) Force Required to Peel a Groundnut. To determine the force needed to peel the groundnut, we must find the force required to rupture the groundnut kernel. Any force below this critical level is enough to peel the groundnut.

According to the research conducted by [12], on the mechanical behaviour of groundnut kernels under compressive load, it was concluded that the minimum force required to rupture a groundnut kernel is 60 N.

2) Design of the Peeling Chamber. Based on the available material, the peeling brush possesses the following features:

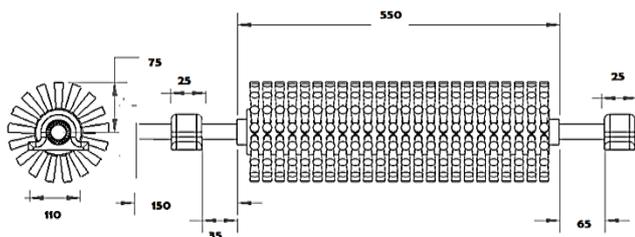


Figure 1 – Shows the Peeling Brush

Based on the geometry of the peeling brush described above, to determine the minimum size needed to cover the entire groundnut being fried, we recall that 5 kg of groundnut has a volume of 0.00664 m³.

The total volume that a groundnut kernel can occupy is:

$$V = \text{volume of peeling cham} - \text{volume of peeling brush}$$

The designers selected a peeling chamber length of 600 mm to accommodate the entire peeling brush and allow free rotation. To determine the minimum diameter, they recalled that:

$$V = \frac{\pi}{4} (D^2L - d^2l) \tag{1}$$

$$\text{therefore } D = \sqrt[2]{\frac{1}{L} \left(\frac{4V}{\pi} + d^2l \right)}$$

$$D = \sqrt[2]{\frac{1}{0.6} \left(\frac{4 \times 0.00664}{\pi} + 0.11^2 \times 0.55 \right)}$$

$$D = 0.158 \text{ m} = 158 \text{ mm}$$

A 170 mm diameter was used to accommodate the space occupied by the shaft and brushes, as shown below.

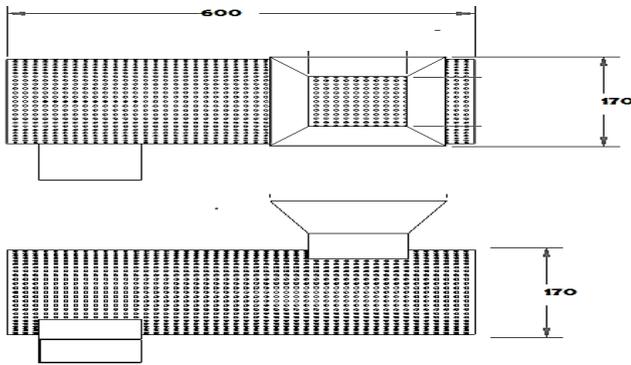


Figure 2 – Shows the Peeling Chamber

3) Speed Required to Peel Groundnut. The force required to peel the groundnut must be less than the minimum rupture force, which is 60 N. To verify this, we note that the centrifugal force resulting from the rotation of the brush is given by:

$$F = \frac{Mg\omega^2 d}{2} \quad (2)$$

where Mg is the mass of a groundnut; ω^2 is the speed of the peeling shaft; d is the diameter of the peeling brush.

Therefore,

$$\omega = \sqrt{\left(\frac{2F}{Mg d}\right)} = \sqrt{\left(\frac{2 \times 60}{5 \times 0.11}\right)} = 14.77 \text{ rad/s}$$

$$\text{Speed is } N = \frac{60\omega}{2\pi} \quad (3)$$

$$N = \frac{60 \times 14.77}{2\pi} = 140 \text{ rpm}$$

4) Time Required for Peeling the Groundnut. The time taken to peel 4.50 kg of fried groundnut seeds was 14 minutes (0.23 hours), at which point the red skin of the groundnut stops emerging. The machine's capacity is therefore

$$\text{Capacity} = \frac{\text{Weight}}{\text{Time}} = \frac{4.50}{0.23} = 19.6 \text{ kg/hr}$$

Mode of Operation. Power is supplied to the machine from an external source when the electric motor is activated, causing it to rotate and transmit rotational motion to the shaft. The system then transfers this motion to the peeling brush. Operators pour the roasted groundnuts into the hopper, where the machine peels them, and the blower simultaneously removes the red skin before the product is bottled and ready for sale or consumption.

Servicing Safety. Personnel handling oil and solvents may develop skin dermatitis. To lower the risk of infection, apply barrier creams to the hands and wear appropriate gloves. When using solvents, ensure the area is well ventilated, preferably with forced air circulation. It is also advisable that all personnel wear eye protection and a filter mask with an organic vapour cartridge. Overalls, such as laboratory coats or boiler suits, should be worn at all times. When moving weights, workers must wear protective footwear regardless of the weight's size. After handling oil and solvents, workers must wash their hands thoroughly with a hand cleaner to remove all residues. Maintenance personnel must disconnect all electrical equipment from the power supply before performing maintenance. Only qualified electrical personnel should carry out servicing or repairs involving the electrical system.

Maintenance. To prevent unexpected breakdowns or failures, the machine requires regular maintenance, either daily or weekly, depending on its usage. Maintenance personnel should always apply oil and grease to bearings to minimise friction and wear from contact.

Manufacturing Process. The fabrication team followed these steps to produce the various parts of the peeler. They carried out the marking-out processes using a measuring tape, ruler, scribe, steel rule, punch, and engineer's triangle. The technicians used a hacksaw to cut the angle bar and a cutting disc to cut the sheet metal. They first joined parts of the main frame by tacking with arc welding, then checked the top and bottom frames for squareness and alignment before completing the welds. The machinist centre-drilled the shaft on the lathe and machined it to the required dimensions. The welders used electrodes with a standard wire gauge size of 10. Throughout fabrication, the team measured various dimensions based on the machine's blueprint to ensure precision.



Figure 3 – Shows the complete construction of the groundnut peeling machine

Data Analysis. The experimental samples, including the initial mass of roasted groundnuts before peeling and the mass after peeling, were measured using both manual and machine-operated timing at various revolutions per minute. These samples were coded and analysed using the Statistical Package for the Social Sciences (SPSS) version 25.0. The samples were graphed using E-View 7.0 statistical software. The statistical techniques employed included descriptive statistics (coefficient of variability), analysis of variance, and pairwise comparisons.

Table 2 – Shows the Operation of Peeling Groundnuts

No	Manual Time of Peeling Groundnut (mins)	Machine Operated Time of Peeling Groundnut (r/min)					Weight of Peeled Groundnut After Peeling (Kg)
		300	600	900	1200	1500	
1	15.00	2.70	2.00	1.90	1.50	1.30	0.97
2	22.00	3.50	3.10	2.40	1.90	1.50	1.97
3	30.00	4.50	3.10	2.90	2.10	2.10	2.95
4	45.00	5.80	4.20	3.50	2.95	2.95	3.80
4	58.50	7.60	5.10	4.50	3.20	3.90	4.50

Table 3 – Tests of Between-Subjects Effects

Dependent Variable: Sample					
Source	Sum of Squares	Df	Mean Square	F	Sig.
BRM	366.953	4	91.738	2.024	.130
M/C operated	3989.747	5	797.949	17.604	.000
Error	906.557	20	45.328		
Total	5263.257	29			

Notes: R² = .828 (Adjusted R² = .750)

The experimental design for evaluating the machine's performance depends on the mass of groundnuts before and after peeling. Analysis of the machine operating at both manual and automatic settings across various revolutions per minute shows that operation at all revolutions was statistically significant (p-value < 0.05). The data fit the model well, with a correlation coefficient of 0.828, indicating an 82.8% relationship between the parameters. The mass before peeling is statistically significant, with a p-value of 0.030, which is below 0.05 at the 5% level. Therefore, it is concluded that the mass before peeling varies significantly, and machine operation at different revolutions per minute produces different results after peeling.

Calculations. Mass of groundnut before peeling = 5 kg; Mass of groundnut after peeling = 4.50 kg; Mass of good groundnut = 3.89 kg; Mass of broken groundnut = 0.61 kg.

$$\begin{aligned}
 \text{Efficiency} &= \frac{\text{Mass of groundnut after peeling}}{\text{Mass of groundnut before peeling}} \times 100 \\
 &= \frac{4.50}{5.00} \times 100 = 90\% \text{ efficient} \\
 \text{Percentage of Breakage} &= \\
 &= \frac{\text{Mass of broken groundnut}}{\text{Mass of good groundnut} + \text{Mass of broken groundnut}} \times 100 \\
 &= \frac{0.11}{0.89 + 0.11} \times 100 = 11\%
 \end{aligned}$$

According to the analysis from the Statistical Package for the Social Sciences, the Social Sciences show a Mean Square Error of 45.328, with a significant mean difference at the 0.05 level.

The least significant difference test indicates that the manual preparation time required for mass before roasting differs significantly from the machine operation times at 300, 600, 900, 1200, and 1500 r/min.

Table 4 – Shows the Peeling Machine Operation Multiple Comparisons

	Peeling Machine Operated (I)	Peeling Machine Operated (J)	Mean Difference (I-J)	Std. Error	Sig.<0.05 at 5%	Decision Rule
Tukey HSD	Human-assisted time	The machine operated at 300 r/min	29.28*	4.258	.000	Sig.
		The machine operated at 600 r/min	30.44*	4.258	.000	Sig.
		The machine operated at 900 r/min	31.06*	4.258	.000	Sig.
		The machine operated at 1200 r/min	31.77*	4.258	.000	Sig.
		The machine operated at 1500 r/min	31.75*	4.258	.000	Sig.

This suggests that the manual time for mass before roasting produces different values when the machine operates at 300, 600, 900, 1200, and

1500 r/min. Furthermore, the data emphasise that the machine's performance is not consistent across the different revolutions per minute.

Table 5 – Shows the Comparative analysis

	N	Mean	Std.	CV=Std./ Mean x100	Efficiency
Semi-automated Peeling machine operated	30	3.50	1.74	49.7%	Efficient
Human-assisted Time	30	8.38	13.47	160.7%	Very Low Efficiency
Before peeling mass in kg	5	3.00	1.58	52.7%	Moderately Efficient
After peeling the mass in kg	5	2.94	1.55	52.7%	Moderately Efficient

Notes: CV = Coefficient of Variability; a smaller CV indicates more efficient machine operation.

Table 6 – Shows the Pair comparison test

	Mean	Std.	Std. Error	T	Df	Sig. (2-tailed)	Sig.<0.05 at 5%
Before peeling mass in kg - After peeling mass in kg	.062	.036	.016	3.89	4	.018	Sig.

Descriptive statistical analysis shows that a peeling machine operating at different revolutions per minute is more effective than manual peeling. The mass measured before and after peeling, reported in kilograms, consistently indicates an efficiency of 52.7%. However, results from the pairwise comparison test reveal that the difference in mass before and after peeling is statistically significant at the 5% level (p-value = 0.018; 0.018 < 0.05). This finding suggests that the mass measured before peeling and after peeling is not the same in kilograms.

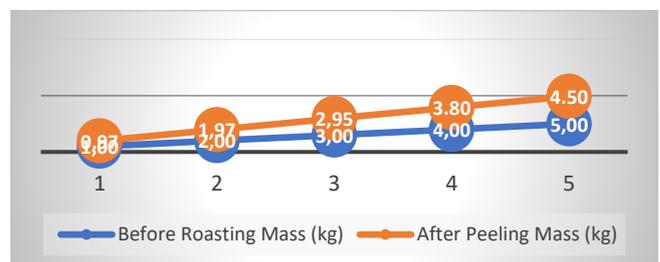


Figure 4 – Shows the relationship between groundnut before roasting and after roasting, peeling

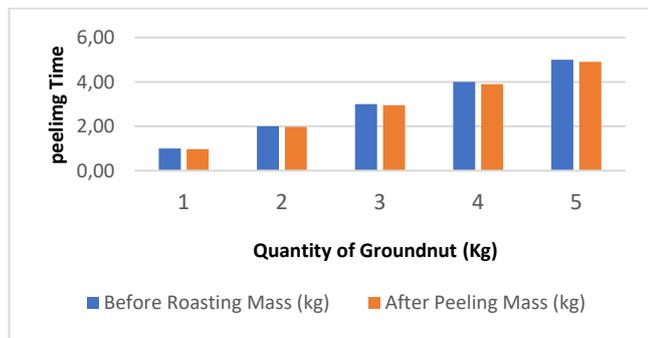
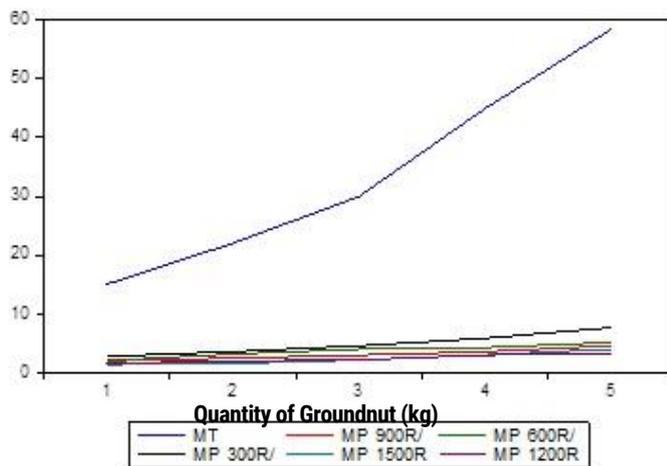


Figure 5 – Shows the relationship between peeling time and the quantity of groundnut



MT- Machine Time
MP- Machine Processing Speed

Figure 6 – Shows the relationship between machine time and the quantity of groundnuts peeled

The graph of MT and MP at various revolutions per minute shows that MP 1200r/min has the lowest processing machine speed, followed by MP 1500r/min, MP 900r/min, MP 600r/min, and MP 300r/min, compared to manual machine processing time. Therefore, processing times are significantly more efficient at MP 1200r/min and MP 1500r/min. As a result, MP 1200r/min demonstrates the best processing capability for groundnuts.

RESULTS AND DISCUSSION

The research team tested the machine after fabrication to evaluate its performance. Tables 2 and 3 present the numerical results from the experimental runs. These results were analysed using SPSS (Statistical Package for the Social Sciences). The experimental data showed a good fit with a value of 0.828, indicating an 82.8% correlation among the parameters. The mass before peeling was statistically significant (p -

value = 0.030), which is less than 0.05 at the 5% significance level. The peeling chamber operated at different revolutions per minute and proved more efficient than manual peeling, as shown by mass measurements before and after peeling, expressed in kilograms. The masses before and after peeling were moderately similar, with an efficiency of 52.7%. It was observed that the mass before operation varied at different revolutions per minute, leading to different peeling outcomes. Hand-assisted peeling of 5 kg of groundnuts takes about 3-5 hours, whereas a semi-automated machine can peel the same amount in 14 minutes. The machine achieves a peeling efficiency of 90%, with a broken percentage of 11%.

CONCLUSIONS

It is worth noting that completing this project marks a significant milestone in developing technology for locally produced groundnut peeling machines suitable for the food industry. This study involved designing and manufacturing a roasted-seed groundnut peeling machine from readily available materials, ideal for local production of fried, peeled groundnut seeds. The machine is more straightforward to operate, repair, and maintain. Its technology is more affordable than that of imported peeling machines. It has low operating costs, is compact, moderately heavy, produces minimal noise, and works without vibration. The experimental process showed a strong correlation coefficient of 0.828, indicating an 82.8% association among the parameters. The mass before peeling is statistically significant at 0.030, which is less than 0.05 at the 5% level. Therefore, it is concluded that the mass before peeling varies significantly, and the machine operating at different revolutions per minute yields different outcomes after peeling. Peeling 5 kg of groundnuts manually takes about 3 to 5 hours, whereas using this machine takes only 14 minutes. The machine achieves a peeling efficiency of 90%, a broken percentage of 11%, and a capacity of 19.6 kg/hour of peeled groundnuts; this clearly demonstrates that peeling fried groundnut seeds with this machine is more advantageous than by hand and represents an improvement over the previous design.

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Author Contributions

Study design (B. Dirisu), data collection (B. Dirisu), analysis (O. M. Olabanji), writing (B. Dirisu), critical review (P. K. Oke).

Conflicts of Interest

The authors declare no conflicts of interest.

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