Development of a Locally Made Coconut DE husking Machine for Small Scale Farmers

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Abstract
Coconut plays an important role in the society. It provides food, edible oil, industrial oil etc. Processing of coconut for any purpose requires DE husking. The methods for DE husking coconut could be manual or mechanized method. These methods have limitations. While the manual method affects the production rate and is more hazardous and harmful to the user, the mechanized method sometimes has the problem of nut cracking, availability and affordability by the local small-scale famers. This machine eliminates these challenges and limitations to a greater extent. It is specially developed using best techniques and materials carefully selected locally to take care of the nut cracking, affordability and availability for local farmers. It deploys one electric motor (1hp, 1400rpm) to drive two shafts using the combination of chain and sprocket. A gear box is fixed between the shaft and the motor to reduce the rotational speed from 1400rpm to 24rpm. Two metal cylinders with series of spikes, attached to the rotary shaft are used to remove the husk from the coconut. The machine was tested and the result obtained shows the efficiency of 84%. The average DE husking capacity was 133 nuts per hour. From the result analysis, the machine performance indicates that the DE husking time is a function of the size of coconut. However, the machine is recommended for use by small-scale farmers.

Keywords: *Coconut, DE husking, Machine, Mechanized method, Small-scale Famers*

1. Introduction

Coconut is one of the world's most useful and important perennial plants, it belongs to a family called 'cocos nucifera'**.** Coconut plays an important role in the economic, social and cultural activities of millions of people in Akwa Ibom State, Nigeria and world at large. Coconut provides food, edible oil, industrial oil and health drink for humanity [1]. Bisecting an individual coconut fruit into equal halves exposes the underlying layers which are the outer layer (exocarp), a thick fibrous middle layer (mesocarp), underneath these is the hard-brown protective (endocarp) or shell. The nut varies between 147 mm and 196 mm in diameter and an absolute profile length of 245 mm and 294 mm. Underneath the shell is a thin, white fleshy laye**r,** which at maturity is approximately 12.25 mm thick called "coconut meat" or copra [2]. The interior of the nut is hollow

and partially filled with a watery liquid called coconut milk. At an early maturity stage, the meat is soft and jelly-like and becomes firm at full maturity [3]. The meat of the immature coconut fruit can be made into ice cream while that of a mature coconut fruit can be eaten fresh or used for making shredded coconut and livestock feed. De-husking is the first operation in processing of coconut; it is the process of removing the outer shell of the coconut seed to expose the nut. This can be done both manually and mechanically [4]. De-husking of coconut mechanically adopts the principle of manual de-husking, where a sharp tool is pierced into the coconut by force and sharing action between the husk and the coconut which result in the removal of the husk [4]. The mechanization in agricultural operation is of age and a lot of work has been done to make the peeling operation easier in different post-harvesting processing. An earlier attempt was made on the coconut peeling method [5]. Mechanized coconut peeling is mostly foreign-made [6]. He also noted that machines for coconut peeling have been developed since early 1930's in an attempt to initiate the traditional method but had failed due to the incapability of these machines to compete with the manual labor in terms of speed, efficiency, ergonomics and maneuverability. Generally, coconut is de-husked manually using either a machete or spike, which requires skilled labor, and it is very tiring and tedious. In order to avoid the danger associated with injury, unnecessary stress, and much time spent in the manual method of de-husking operation, the mechanized approach is employed. However, in this approach, the challenge often encountered by local famers in processing their coconuts with the intention of consumption is that the nuts sometimes get cracked open during the operation, which leads to the coconut juice spilling out into the machine; resulting in high percentage wastage/loss and gradual damage to machine. In order to avoid these risks, the locally made coconut DE husking machine is developed; where the speed of the rotating blades is well regulated and adjusted to a manageable speed in order that the de-husking process is completely done without damaging the coconut. Also, to avoid the high cost of production and importation of the machine, selected locally available materials are used for this work for affordability and accessibility [7, 8].

2. Literature Review

Coconut de-husking is the first operation in coconut processing, which is required for refining process of the coconut to final products. Over the years, researchers have attempted to develop different types of coconut de-husking machines, few of which are mentioned here:

Kwangwaropas (1992) [9], evaluated the performance of hydraulically operated coconut de-husking machine consisting of a 1.5 kW, 220 Volts' electric motor to drive a hydraulic pump, operated by two persons at average de-husking period of 10 -12 seconds/coconut. Owolarate *et al.*, (2008) [10] developed a second-class lever mechanism type tool for aiding manual de-husking of coconut. Three types of tools were tested to de-husk the Nigerian tall coconut variety having sphericity of 75 - 81 percent. An average de-husking capacity of 12, 35, and 47 nuts per hour respectively were recorded. Gajakos *et al*. (2008) [11] developed a power operated coconut de-husker, which was operated on a 3-phase, 5hp electric motor. The de-husking unit of de-husker consisted of two cylinders namely: de-husking cylinder and idle cylinder. Husk was removed by triangular shaped teeth mounted on de-husking cylinder, which penetrated into the husk and pulled it away from the coconut. Average de-husking time for a single coconut was recorded to be 16.56 seconds. De-husking efficiency, de-husking capacity, damage percentage and average power consumption were observed as 82.0%, 200-225 nuts/hr, 18.0% and 4.43Hp respectively. Ghosal and Sarkar (2013) [12] studied and evaluated the performance and ergonomics of a power operated coconut de-husker. Different performance parameters namely; de-husking efficiency, de-husking

capacity and ergonomical considerations like heat rate, oxygen consumption rate etc. were measured during testing. De-husking capacity and de-husking efficiency were observed as 300 nuts/hr and 92% respectively. Onyenanu and Uwadibe (2024) [13] developed a low cost, medium speed coconut de-husker. It consisted of main frame, electric motor, gear box, cam and follower, lifter, holding mechanism and splitting mechanism. The performance of the de-husker was evaluated on the basis of de-husking time, output capacity, de-husking efficiency and operating cost etc. The average de-husking time required to de-husk one coconut was 30.6 sec. and output capacity was 118 nuts/hr, which was 40% higher than the manual de-husker. The average de-husking efficiency of the developed power operated de-husker was 96.62%.

Many of the coconut de-husking machines that have been developed so far, works on principles and applications, which usually result in breakages of the coconut shell; thereby causing wastage. The design specification of foreign machines poses difficulties for small-scale manufacturing in Nigeria. Also, foreign technology in most cases though functionally appropriate, does not meet the entire range of socio-economic conditions applicable in small scale manufacturing. The inappropriateness of these foreign technologies had created the need to develop an equipment from local materials, manufacturing technology and manpower; thus, making it available and affordable [8, 13]. This machine is designed for an efficient and dependable means of de-husking coconut. It will not only reduce the wastage involved during coconut processing, but shall bring about an increase in productivity, reducing human labor and accidents involved with the use of conventional crude method of de-husking. Besides, it is specially designed to be affordable and available to local farmers and small-scale industries.

3. Materials and Methods

3.1 Materials

The various components used in the development of this coconut de-husking machine include: frame, casing, gears, rollers, bearings, spikes, motor, etc. These materials were carefully selected for the design and development of the machine, based on the following considerations to enhance its efficiency and functionality: ductility, complexity, reliability, resistance to corrosion, tensile strength, availability, weight, machinability etc. Table 1 shows the different machine components, materials used and justification for selection.

Table 1: machine components and materials used

Component	Material	Justification
Frame	Mild steel	High tensile strength to weight ratio.
spikes	Mild steel	High tensile strength and good machinability
Shaft	Mild steel	Hardness and high strength
Sprocket	Steel	High strength
Chain drive	Steel	High strength
Adjuster	Steel	Machinability
Bolt and nuts	Alloy steel	Hardness and high strength
Drainage	Mild steel	High strength and good malleability
Discharge	Mild steel	High tensile strength and good malleability

3.1.1 Electric Motor

Due to the fact that the operation of this machine is mechanically oriented, the drive mechanism plays a very important role. A three-phase induction motor was selected for this purpose [14]. This motor is generally used in various kinds of industrial drives. It acts as the driver wheel connected

through a coupling system directly to the gear box that acts as the driven wheel. The rotation speed of the output shaft of the motor is 1400rpm. The motor's output shaft is connected directly to the gear box through a coupling system that will completely reduce the transmission losses. The motor bed is rigidly fixed onto the frame of the machine. Caution was taken such that the motor shaft and the gear box input shaft were attached in a parallel line to minimize vibrations and completely utilize the power of the motor [15, 16].

3.1.2 Machine Frame

The frame is the main supporting structure upon which other components of the machine are mounted on. The frame is a welded structure constructed from 50x50x5mm mild steel angle iron with dimensions of 665mm length, 800mm width, and 740mm height. The steel is rigidly fixed onto the frame so that the vibration and weight are uniformly distributed to the support frame below [16]. The geometric structure of the main frame was designed to give a good shape and better stability to the entire structure.

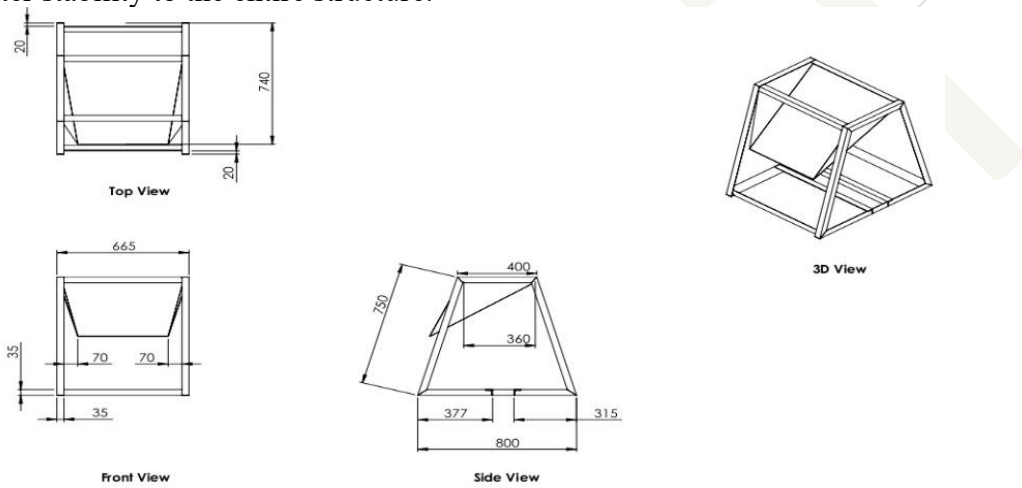


Figure 1: Frame work

3.2 Methods

To successfully developed an efficient coconut dehusking machine for small-scale farmers and industries and to ensure that the materials selected and fabricated fits together properly, the following operations and methods were adopted:

a) The cutting operation

The required shape of the work piece was removed by means of shear deformation; electric cutter was used. The cutting was accomplished by using single-point or multiple tools [17].

b) Drilling operation

The drilling operation was done to provide pathways for the joining elements such as the rivets, bolts and nuts.

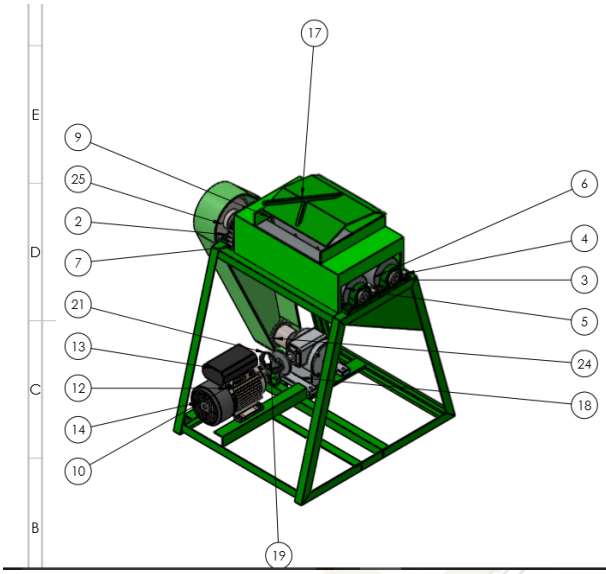
c) Welding operation

The welding operation was done using suitable electrodes and welding thongs. It was carried out to bring the various parts been cut together to form the frame and other components of the machine.

3.3 Design and Construction Considerations

For optimum performance and easy maintenance of the coconut de-husking machine, it was produced based on the following considerations:

- Simplicity of design, to meet the required standard and specifications like size, weight, input, output, and the power consumption.
- Mechanical strength of the material, used to ensure their durability and reliability.
- Size of the fruit, which reduces as the husk is progressively removed; thereby controlling the space between the rollers and projections of the spikes from right to left end of the machine, to enable effective gripping of the fruit's nut as the husk is been removed.
- Breakage and distortion of length of husk/coir fiber extracted, which resulted in the use of rectangular shaped spikes and careful design/selection of gears and pulleys to meet the required synchronized speeds of the de-husking and conveying units.
- Availability of materials locally, in order to reduce cost of production and maintenance of the machine.



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Frame		1
2	BLOCK		4
3	BEARING		4
4	ISO 8676 - M16x1.5 x 45-S		4
5	Husking Drum		1
6	Husking Drum Driver		1
7	ISO - Spur gear 5.5M 37T 20PA 25FW --- S37B50H40L20.0S1		1
8	ISO - Spur gear 5M 24T 20PA 25FW --- S24B50H40L20.0S1		1
9	Top Cover		1
10	MotorCasing		1
11	MotorFrontCover		1
12	MotorBackCover		1
13	ConnectionBox		1
14	MotorFanCover		1
15	MotorShaft		1
16	MotorBolt		4
17	Top Cover Opening		1
18	Gear Box		1
19	Coupling - A		1
20	Coupling - B		1
21	Flexible Linkage		4
22	ISO 4162 - M5 x 16 x 16-S		8
23	ISO - 4161 - M5 - S		8
24	Chain wheel ISO - 20Z 10A-1 --- 20SB75H70L20.0S1		1
25	Chain wheel ISO - 35Z 10A-1 --- 35SB75H30L20.0S1		1
26	Chain Cover		1

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Figure 2: Diagram of the Developed Coconut De-husking M for Machine for Small-Scale Farmers

3.4 Design Analysis of the Dehusking Machine

Some data on the loads acting on the coconut to de-husk it is required. The husk is removed from the machine through the shear force exerted by the fixed toothed rollers in the machine. In relation to that, the amount of shear load required to de-husk the coconuts have been determined.

For shear yield strength of coconut fruit, equation 1, according to Ovat *et al.*, 2019 [18] was used.

$$\tau_{yt} = 0.577\ \sigma_{yt} \quad (1)$$

Where: $\tau_{yt} = shear\ yield\ strength$

$\sigma_{yt} = tensile\ yield\ strength = 175\ N/mm^2$

3.4.1 Power required by the machine

The total power, (P) required by this machine to de-husk one coconut is determined using an equation as specified by Rajput *et al.,* (2006) [19].

$$\boldsymbol{P_T = P_{spikes} + P_{shaft}} \quad \textbf{(2)}$$

Since the spikes and shaft are mechanically coupled together

$$P_T = P_{spikes\ with\ shaft}$$

$$\boldsymbol{P_{spikes\ with\ shaft} = T_{spikes\ with\ shaft} \times V_{spikes\ with\ shaft}} \quad \textbf{(3)}$$

$$\boldsymbol{V_{spikes\ with\ shaft} = \frac{2\pi N}{60}\left(\frac{m}{s}\right)} \quad \textbf{(4)}$$

$T_{spikes\ with\ shaft}$ is the torque (Nm)

For the diameter of shaft used to transmit the rotary motion from the electric motor to the de-husking chamber, equation 5, was used:

That is, torque transmitted by the shaft, $T = \frac{P \times 60}{2\pi N}$ (5)

Also, for torque transmitted by the solid shaft, equation (6) was used according to Oboh, *et al*., (2025) [15].

$$T = \frac{\pi}{16} \times \pi \times d^2 \quad (6)$$

3.4.2 Selection of Gears

Due to availability, ease of design and maintenance, two spur gears with pressure angle of 20 º, 24 driving teeth and 37 driven teeth, suitable for the heavy loads were carefully selected for the machine.

3.4.3 Reduction Gearbox

The worm gears are widely used for transmitting power of high velocity ratios. The gear box used in this machine has a speed ratio of 57.5:1. This reduces the speed from 1400 rpm to 24 rpm. The mechanism used in the gear box is the worm gear mechanism.

3.4.4 Chain and Sprocket

The following variables were used for the design analysis of the chain and sprocket mechanism used in the machine:

Pitch diameter of driving sprocket = D_1
Pitch Diameter of driven sprocket = D_2
Number of teeth on the driving sprocket = T_1
Number of teeth on the driven sprocket = T_2
Speed output of the gear box = N_A
Speed of the rolling shaft = N_B

From R. S. Khurmi (2005) [20]:

$$N_A T_1 = N_B T_2 \quad (7)$$

$$\therefore Speed\ ratio = \frac{N_B}{N_A} = \frac{T_1}{T_2} \quad (8)$$

Pitch Circle Diameter, D:

$$D = p\ \mathrm{cosec}(180/T) \quad (8)$$

It implies that: $P = d \sin\frac{\theta}{2}$ (9)

$$\therefore \quad \theta = \frac{360}{T} \quad (10)$$

Center distance of the sprocket:

$$C = \frac{1.5\, D_O}{VR^{1/3}} \quad (11)$$

Where:

D_o is the pitch circle diameter of the larger sprocket
D_i is the pitch circle diameter of the smaller sprocket
C is the center distance between sprocket, and

VR is the velocity ratio $= \frac{N_1}{N_2} = \frac{T_2}{T_1}$

3.4.4.1 Length of chain drive

According to [19], the length of chain drive was calculated using equation 12:

$$L = \frac{P}{2}(T_1 + T_2) + 2x + \frac{(r_1 - r_2)^2}{x} \quad (12)$$

$r_1 = pitch\ radius\ of\ the\ bigger\ sprocke$

$$r_1 = \frac{p}{2}\ cosec\frac{180}{T_1} \quad (13)$$

$$r_2 = \frac{p}{2}\ cosec\frac{180}{T_2}$$

4. Results And Discussion

4.1 Input parameters

The parameters used for the general design and development of the dehusking machine and for the evaluation of the models presented in section three (3) of this work are captured in Table 2.

Table 2: Input parameters for the analysis

S/N	PARAMETER	VALUE	SYMBOL	UNIT
1	Motor power rating	1	p_m	Hp
2	Number of teeth of the smaller sprocket	15	T_2	
3	Number of teeth of the larger sprocket	38	T_1	
4	Rotational speed of the motor	1400	N_A	r/min
5	Shaft diameter	0.02	D_S	m
6	Tensile yield strength	175	σ_{yt}	N/mm^2
7	Speed reduction ratio	57.5:1	N_R	

4.2 Results from Design calculations

4.2.1 Shear and tensile yield strength

According to Karen A, (1992) [21] and [17], the shear and tensile yield strength was obtained from equation 1, as follows:

$\tau_{yt} = 0.577\sigma_{yt}$

$\sigma_{yt} = 175N/\text{m}^2$

4.2.2 Machine power received

From equation 4

$$V_{shaft} = 2 \times \pi \times \frac{1400}{60} = 146.6\ m/s$$

Shaft diameter = 20mm = 0.02m

Power from the electric motor (1Hp) = 0.75 kW

From equation 5 according to [21, 22], torque produced by the machine:

$$T = \frac{p\ X\ 60}{2\pi N} = T = \frac{0.75\ X\ 1000\ X\ 60}{2\pi\ X\ 1400} = 5.1157Nm$$

This value, $5.1157Nm$ *becomes the input torque of the gear box train*

Note: Gearbox of 57.5:1 speed ratio was used. This implies that *N = 24rpm*

Therefore, based on mechanical advantage, output toque of the gear box is:

$$T = 57.5 \times 5 = 287.5\ Nm$$

Torque on the rollers = $\frac{no\ of\ teeth\ on\ the\ driven\ sprocket\ X278.5}{no.of\ teethon\ the\ driving\ sprocket} = \frac{38\ X\ 278.5}{15} = 705$Nm

$$P = \frac{2\pi NT}{60} = \frac{2\ X\ \pi\ X\ 24\ X\ 705}{60}$$

$$\therefore P = 1.8\ kW$$

4.2.3 Speed ratio

From equation 7,

The speed ratio = $\frac{N_b}{N_a} = \frac{T_a}{T_b} = 38/15 = 2.5$

T_a = number of teeth on the larger sprocket

T_b = number of teeth on the smaller sprocket

4.2.4 Centre distance

According to [15, 19], the centre distance was calculated from equation **11,**

$C = \frac{1.5\ D_o}{VR^{1/3}}$

4.2.5 Length of chain

Pitch = p; P = 0.012 m; X = 0.685m

Let, $r_1 = 72.66mm = 0.072m$

$r_2 = 28.89mm = 0.028m$

Using equation 12, length of chain is:

L = 1.691 m

4.3 Machine performance analysis

The de-husking capacity and efficiency of the developed coconut dehusking machine was to actualize the objective of the work. This was established through ten experiments. The capacity and efficiency of the locally produced coconut de-husking machine were determined with the following equations:

4.3.1 De-husking capacity

According to Sanuddih, A. B. (2015) [23], this is the ratio of number of de-husked nuts and the time of operation, in hours.

Thus, $C_d = \frac{D_a}{T_0} X\ 60\ X\ 60$ (14)

Where:

C_d =*de-husking capacity*

D_a= *de-husked nuts*

T_o = *time of operation (hr)*

Hence, from equation (14), the results obtained for all de-husking capacity are presented in Table 3:

$$C_d = \frac{5}{110.1} X\ 3600 = 107 \text{ coconuts/hr.}$$

Table 3: Result for of the performance evaluation of the coconut de-husking machine.

s/n	Size (mm)	D_{in}	D_a	Time for each Dehusking (sec)	Total Time (sec)	Efficiency (%)	Capacity (coconut/hr)
1	114.6	5	4	20.4	102	80	141
2	120.2	5	3	19.7	98.5	60	110
3	123.0	5	4	22.4	108	80	133
4	124.5	5	5	25.2	124.4	100	145
5	148.4	5	5	26.8	130.1	100	138
Average				22.9	112.6	84	133

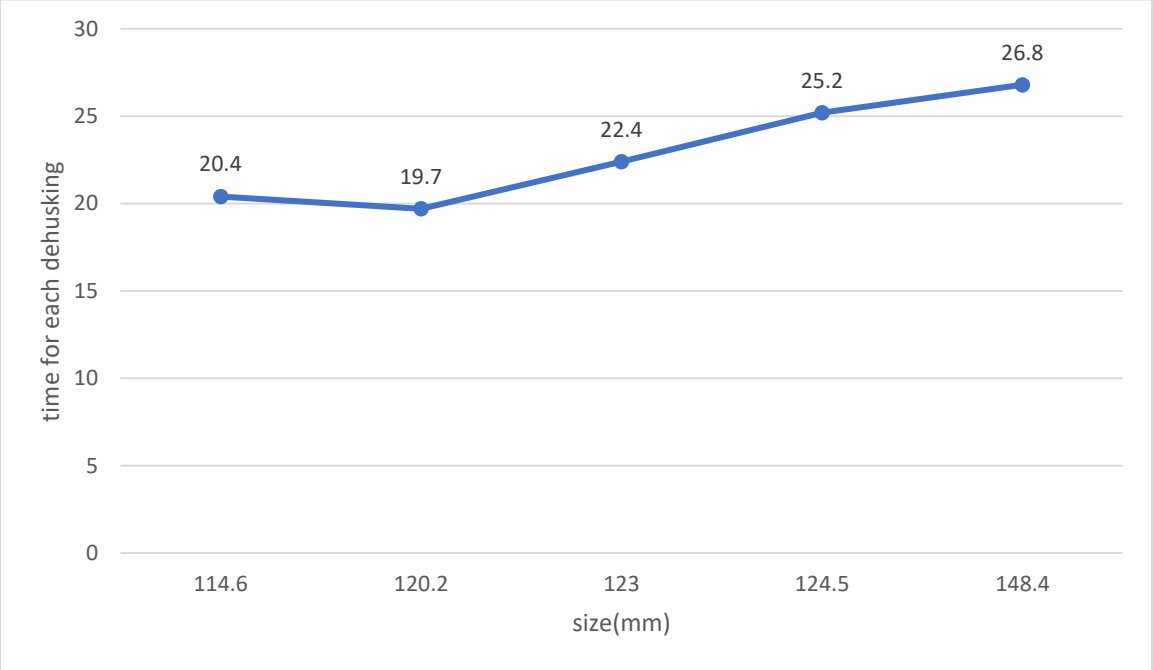


Figure 3: Result of the performance evaluation of coconut dehusking machine

From Table 3 above, the total time to de-husk a coconut varied from 21 to 30 sec. Therefore, the average time to de-husk a dry coconut is 22.9 sec. From the graph, Figure 3, as the size of coconut increases the time for dehusking also increases. The de-husking capacity of the machine is determined from the numbers of de-husked nut and the time of operation in hour. Therefore, the average de-husking capacity of the machine is found to be 133 nuts/hr for a dry coconut.

5.0 Conclusion

The developed coconut de-husking machine was designed for small-scale industries and local farmers in the agricultural and rural areas. The operation and maintenance of the machine is simple and inexpensive. Load required for the de-husking of a coconut varies with respect to size and drying rate of the coconut [7, 24, 25, 26]. Thus, machine can produce an average of 133 nuts of coconut per hour. Introducing this machine to small-scale industries and farmers, especially in rural communities will reduce, the risk involved in the use of spikes when de-husking the coconut, dehusking time and eliminate the skilled manpower.

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