DEVELOPMENT OF COCONUT HUSK FIBRE SEPARATOR

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[1]Adesina, B. S*., [1]Akinyemi, D. O., [2]Aina, E. O., [1]Ogunfuwa, O. M. and [3]Bolaji, O. T.
[1]Department of Agricultural and Biosystems Engineering, Lagos State University of Science and Technology, Ikorodu, Nigeria.
[2]Department of Agricultural and Bio-Resources Engineering, Federal University of Agriculture, Abeokuta, Nigeria.
[3]Department of Food Science and Technology, Lagos State University of Science and Technology, Ikorodu, Nigeria.

*Corresponding Author's Email: *adesina.bs@lasustech.edu.ng, Tel. +2348033805040*

ABSTRACT

Coir fibre and cocopeat can be extracted from coconut husk using either traditional or mechanical method. The traditional production of fibres and cocopeat from the husks is a laborious and time-consuming process that requires 10-12 months of anaerobic (bacterial) fermentation. However, mechanical processing using either defibering or decorticating equipment can be used to process the husks after only five days of immersion in water tanks. In this work, a coconut husk fibre separator was fabricated and tested. The coconut husk machine consists of the following units; electric motor, defibering chamber, outlet, pulley, belt, bearing, beaters, shaft, frame, hopper and the stands. The machine is powered by three phase electric motor of 2.5 kW running at a speed of 1260 rpm through a pulley which is keyed directly to the motor shaft. The coconut husk was soaked for 5 days and fed into the machine through the hopper and separated in the defibering chamber by means of the beating blades. The result of the test shows that the defibering efficiency is 82% while the machine capacity is 82.68 kg/hr. The machine can be used to process wet coconut husk for easy separation of quality coconut fibre and cocopeat.

Keywords: Coconut, Husk, Fibre, Separator, Cocopeat, Defibering

1. INTRODUCTION

Coconut fruit is among the 20 important crops in the world (Vidhan and Udhayakumar, 2013). The coconut provides a nutritious source of juice, milk and oil that has fed and nourished populations around the world for generations (Lihua, 2015). On many Islands coconut is staple in diet and provides the majority of the food eaten (Mani and Jothilngam, 2014). Nearly, one third of the world's population depends on coconut (Adzimah and Turkson, 2015) and (Ketan *et al.,* 2014). The outer layer which is called the husk (Mesocarp) is fibrous and the second layer is an inner stone (Endocarp) and the third layer is the cavity which filled with "coconut water" (Venkataramanan *et al.,* 2014).

Coconuts are grown in several regions of Nigeria, particularly in areas with favorable climatic conditions and soil types. These regions primarily include coastal areas, where the climate supports the growth of coconut palms. Some of the key regions where coconuts are grown in Nigeria include: South-Western Nigeria (Lagos State, Ogun State, Ondo State), South-Eastern Nigeria (Imo State, Abia State), South-South Nigeria (Rivers State, Bayelsa State, Cross River State, Delta State).

According to Nwankwojike *et al*. (2012), the fibrous layer of the fruits is manually separated from the hard shell by a process known as de-husking. As a by-product of coir fibre extraction, large quantities of pith are obtained, which usually accumulate at production sites over the years. Recently, the product has gained commercial interest as a substitute for peat moss in horticultural substrate cultivation (Md. Akhir *et al*., 2009). Low susceptibility to biodegradation and a highly porous structure enables coir pith or cocopeat to absorb large volumes of water (more than 50 per cent by weight), which makes it highly suitable in a potting mixture. For horticultural use, the product has to meet specific chemical and biological standards of pH, electrical conductivity and elemental composition. Repression of sodium and potassium from the cation complex of the coir may be desirable for many sensitive horticultural products. Coco-peat, dried in the natural sun is processed to produce different items namely: coco-peat block, coco-peat briquettes, coco-peat tables (Hyder *et al.,* 2008). Additionally, coir fibre can be utilized in farming as support structures and as a substitute for plastic polybags. Coco-peat is a 100% natural growing medium. It has the ability to store and release nutrients to plants for extended periods and time. It has the ability to hold water rather than shedding it and can be reused for up to 4 years. it is very light and easy to handle (Sathya and James, 2012).

Defibering can be done using two methods which are: traditional and mechanical methods. Before the advent of mechanical milling, fibre extraction is a laborious and time consuming process. After manual separation of the nut from the husk, the husk are processed by various soaking techniques and generally in ponds of salt water or lagoons. This requires 10-12 months of anaerobic (bacterial) fermentation. By soaking the fibers, they are softened and can be decorticated and extracted by beating which is usually done by hand. After washing and drying (in the shade), the fibers are loosened manually and cleaned (Mason and John, 2003).

The coconut defibering machine automatically beats and splits the coconut husks into fine coconut fibre and coco peat (Md. Akhir and Dhiauddin, 1992; Mohd Taufik and Md. Akhir, 2009). Many farmers incinerate or dispose of husks, lacking awareness of the advantages of cocopeat and coir. Consequently, cocopeat and cocofibre remain underutilized yet hold significant promise for small-scale farmers in Nigeria. Access is improving, particularly in Lagos and Ogun states, through training initiatives and support from NGOs and government organizations. Nevertheless, to fully harness their potential, smallholders require improved access to equipment, among other necessities. Efficient separation calls for motorized machinery, with costs ranging from ₦150,000 to ₦500,000 and above. Therefore, there is a necessity to develop a machine capable of separating coco peat and coir fibre, the two primary products derived from coconut husks, which is the major objective of this work.

2. MATERIALS AND METHODS

2.1 Structure of the Machine

The coir fiber separator is made up of a feed hopper, a rotary drum with helically arranged blades, a combing device, filter rods, outlets for coir fiber and coco peat, a power transmission unit, and a main frame that supports these components Coconut husks are introduced through the feed hopper at a consistent rate. A 500 mm diameter rotating drum equipped with helically arranged blades and combing devices on both sides of the frame strikes the husks. The blades effectively beat the husks, allowing them to pass through the combing devices for the separation of coir fiber and coco peat. The coir fiber was blown out of the front outlet while the coco-peat was screened by the filter rods and collected at the bottom outlet. The power from electric motor was transmitted to the rotating shaft through the pulleys.

The exploded, orthographic and isometric views of the coconut husk fibre separator are shown in Figures 1, 2 and 3, respectively. The complete coco peat and coir fibre separator is shown in Plate 1.

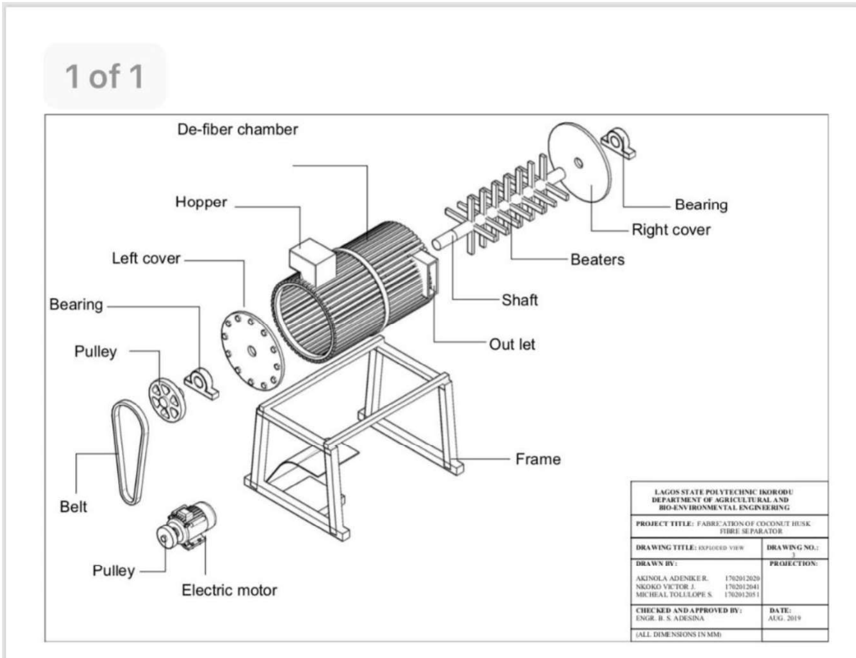

Figure 1. Exploded View of the Machine

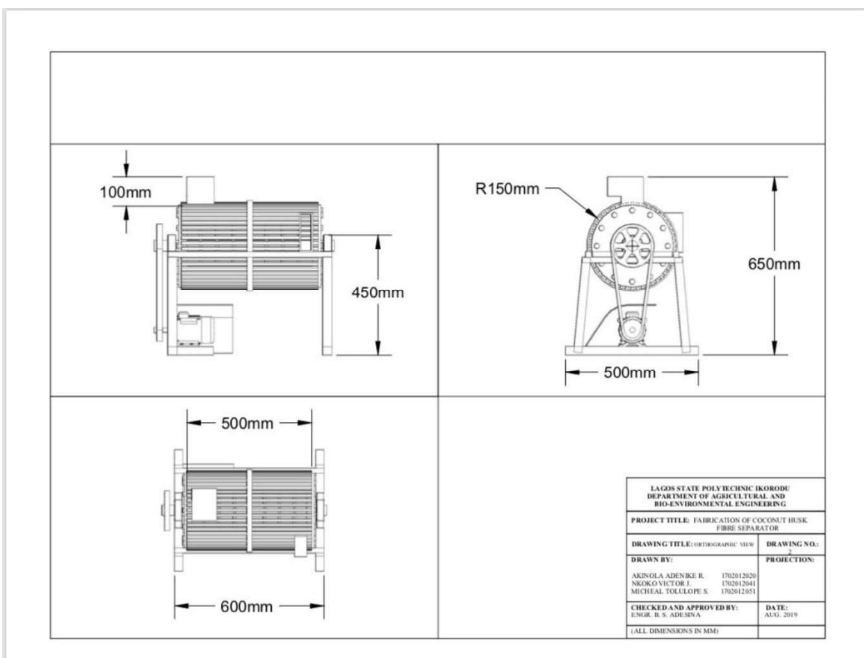

Figure 2. Orthographic View of the Machine

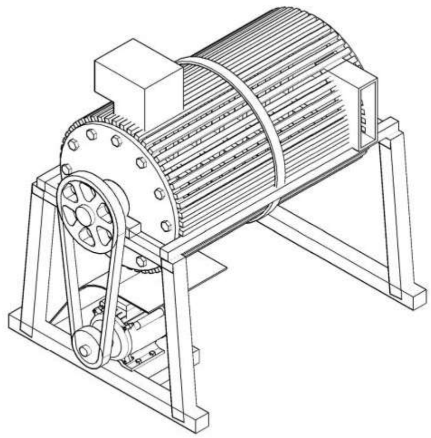

Figure 3. Isometric View of the Machine

Plate 1. The Complete Coconut Husk Separator

2.2 Design Considerations

The aim of the design was based on the machine performing its required functions at low-cost through the use of local materials where possible. Also, the durability, efficiency, availability and affordability of construction materials were taken into consideration. Meanwhile, the structural stability, strong supporting platform, ease of repair and maintenance of the machine were considered. The considerations made for the design of the coconut husk separator was for the driving shaft of the defibering chamber and the material to be able to withstand the combined torsion and bending moment based on maximum shear theory.

2.3 Design Computations

2.3.1 Design for volumetric capacity of the hopper

The hopper is in the shape of a pyramid and it was calculated using Equation 1 given by Khurmi (2009).

$$V_{hopper} = \frac{1}{3}[(\text{volume of the outer frustum}) - \frac{1}{3}(\text{volume of the inner frustum}) \quad (1)$$

$$V_{hopper} = \frac{1}{3}(Ah_o - Ah_i)$$

where,

V_{hopper} is volume of hopper, m^3

A is area of base, m^2

H_o, H_i are heights of outer and inner hopper respectively, m

$V = \frac{1}{3}[(0.303^2 \times 0.38) - (0.15^2 \times 0.1)] - \frac{1}{3}[(0.3005^2 \times 0.38) - (0.1475^2 \times 0.1)]$

$V = 0.010879 - 0.0107128$

$V = 1.66 \times 10^{-4} m^3$

2.3.2 Hopper weight design

The hopper weight (W_h) was calculated using Equation 2 given by Khurmi (2009).

$W_h = \rho \times V x g$ (2)

where,

W_h is weight of the coconut hopper, N

ρ is density of the hopper material (Galvanize steel), kg/m^3

g is acceleration due to gravity, m/s^2

V is volume of hopper, m^3

W_h is $7850 \times 1.66 \times 10^{-4} \times 10$

W_h is 13.03N

The coconut husk weight (W_{co}) is given by Khurmi (2009).

$W_{co} = \rho \times V \times g$ (3)

where,

Wco is weight of the coconut husk, N

ρ is density of the coconut husk, $kg/m^3 = 1065\ Kg/m^3$ (Onwudike, 1996)

g is acceleration due to gravity, m/s^2

V is volume of hopper, m^3

$W_{co} = 1065 \times 1.66 \times 10^{-4} \times 10$

$W_{co} = 1.8$ N

Total weight on the shaft (W_L) was calculated using Equation 4.

W_L is weight of the hopper (W_h) + Weight of coconut husk (W_{co}) (4)

$W_L = 13.03N + 1.8N$

$W_L = 14.83N = 15N$

Say 20N

2.3.3 Design for defibering chamber

Volume of cylinder was calculated using Equation 5 given by Khurmi (2009).

$V_{cylinder} = [\pi(ro^2 - ri^2)h - (l \times b \times t)\ opening]$ (5)

where,

$V_{cylinder}$ is volume of cylinder, m^3

R_o, r_i are radius of outer and inner cylinder respectively, m

h is height of cylinder, m

l is length of cylinder, m

b is breadth of cylinder, m

t is thickness of cylinder, m

W is weight of the cylinder, N

$V_{cylinder} = [\pi(0.105^2 - 0.01025^2) \times 0.6 - (0.2 \times 0.2 X 0.1)\}$

$V_{cylinder} = 1.7 \times 10^{-2} m^3$

The cylinder weight (W) was determined using Equation 6 given by Khurmi (2009).

$$W = \rho \times V \times g \quad (6)$$

where,

ρ is density of the cylinder material, (Galvanized steel), kg/m^3
g is acceleration due to gravity, m/s^2
V is volume of hopper, m^3

$W = 7850 \times 1.7 \times 10^{-2} \times 10$
= 1334.5N

2.3.4 Design for deribering shaft

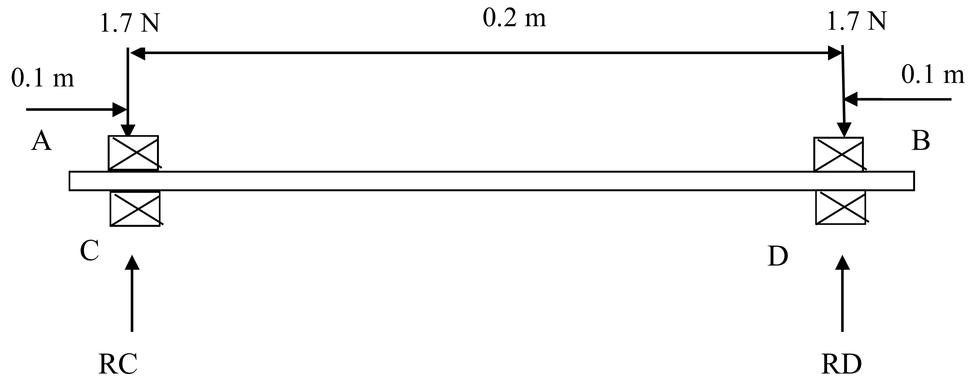

Fig. 4. Deribering Shaft Loading Arrangement

W = 1.7 N (half of the hopper capacity/weight)
L = 0.1 m = 100 mm
X = 0.2 m

Maximum bending moment acts at C and D
$M = W \times L = 1.7 \times 0.1 = 0.17$ Nm.

where,

M is maximum bending moment, Nm
W is weight acting on the wheel, N
L is distance outside the wheel base, m

2.3.5 Torque requirement design

Torque was calculated using Equation 7 given by Khurmi (2009).

$$\text{Torque} = \text{Force} \times \text{shaft radius} \quad (7)$$

$= 15 \times 0.17 = 2.55$ Nm

2.3.6 Design for power

Power was calculated using Equation 8 given by Khurmi (2009).

$$\text{Power} = 2\pi NT \quad (8)$$

where,

π = Constant (3.142)

N is number of revolution, rpm
T is torque, Nm
Number of revolutions (N) = 1260

Power = 2 x 3.142 x 1260 x 2.55
= 20190.49 W

W = 2.02 kW
Say 2.5 kW

2.3.7 Shaft diameter design

Shaft diameter was determined using Equation 9 given by Khurmi (2009).

$$d^3 = \frac{16}{\pi S_s}\sqrt{(K_m M)^2 + (K_T T)^2} \quad (9)$$

where,
M is maximum bending moment, Nm
T is maximum torque, Nm
S_s is allowable shear stress = 41.379 x 10^6 N/m^2
K_m and K_T = Shock loading factors
d is shaft diameter, m

$$d^3 = \frac{5.1}{S_s}\sqrt{(K_m M)^2 + (K_T T)^2}$$

$$d^3 = \frac{5.1}{41.379 \times 10^6}\sqrt{(2.0 \times 0.17)^2 + (1.5 \times 2.55)^2}$$

$$d^3 = 1.2 \times 10^{-7} \times \sqrt{0.1156 + 14.6303}$$

$$d^3 = 1.2 \times 10^{-7} \times \sqrt{14.7462}$$

$$d^3 = 1.2 \times 10^{-7} \times 3.84$$

$$d^3 = 4.6 \times 10^{-7}$$

$$d = \sqrt[3]{0.00000046}$$

$$d = 0.0077\ m$$

$$d = 0.01\ m$$

Force Analysis of Point Load on Defibering Shaft

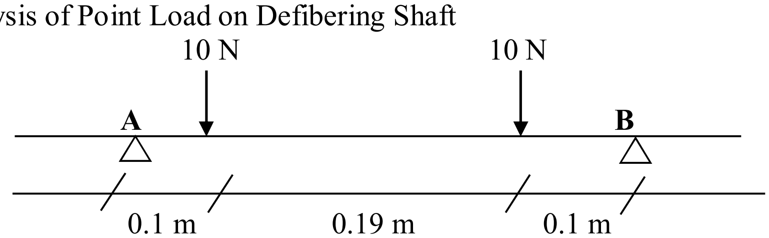

Fig. 5. Point load on defibering shaft

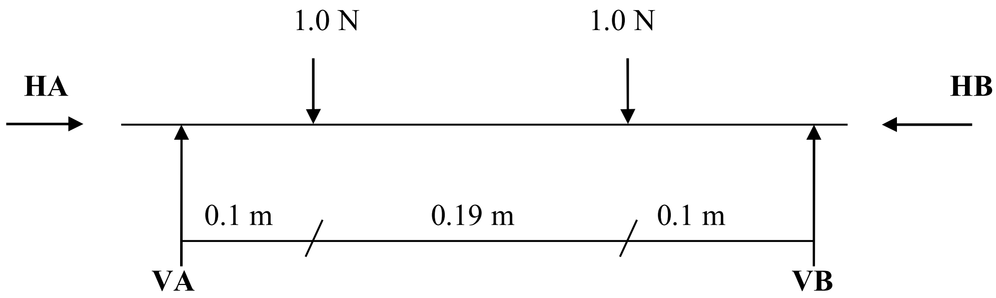

Fig. 6. Forces on defibering shaft

$\sum fx = 0$, HA = 0, HB = 0.
VA + VB = 10 N + 10 N = 20 N.
$\sum MA = 0$.

10 x 0.1 +10 x 0.29 = 0.39 x VB
3.9 = 0.39VB
$VB = \frac{3.9}{0.39} = 10$ N
VA + 10 = 20 N
VA = 10 N.

Consider 1 – 1 at x from A.
$0 \leq x \leq 0.1$

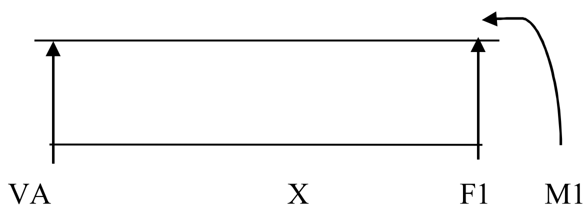

Fig. 7. Forces on defibering shaft at section 1-1

F1 + VA = 0
F1 = - VA = - 10 N
M1 = VAX = 10X
At X = 0.
M1 = 10(0) =0.
At X = 0.1
M1 = 10(0.1) = 1 Nm.

Consider section $0.1 \leq X \leq 0.29$

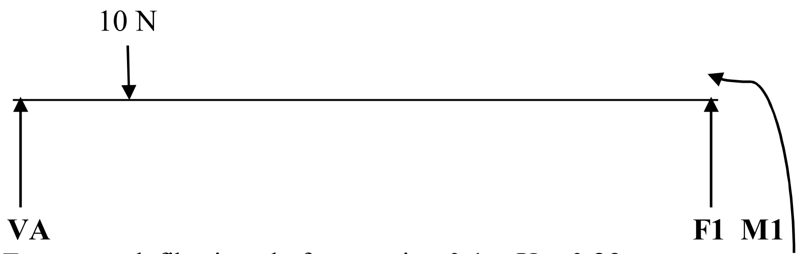

Fig. 8. Forces on defibering shaft at section $0.1 \leq X \leq 0.29$

F1 + VA = 10
F1 = - VA + 10
F1 = -10 + 10 = 0.
M1 = VAX – 10 (X – 0.1)
At X = 0.29
M1 = 10(0.29) – 10(0.29 – 0.1)
M1 = 2.9 – 1.9
M1= 1 Nm

Consider section $0.29 \leq X \leq 0.39$

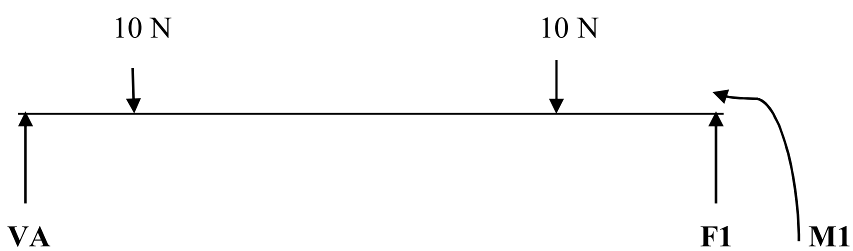

Fig. 9. Forces on defibering shaft at section $0.29 \leq X \leq 0.39$

F1 + VA = 10 N + 10 N
F1 = -VA + 10 N +10 N
= - 10 N + 10 N + 10 N
F1 = 10 N
AT X = 0.39.
M1 = VAX – 10(X-0.1)- 10(X-0.29)
= 10(0.39) – 10(0.39 – 0.1) -10 (0.39 – 0.29)
M1 = 3.9 – 2.9 – 1 = 0.

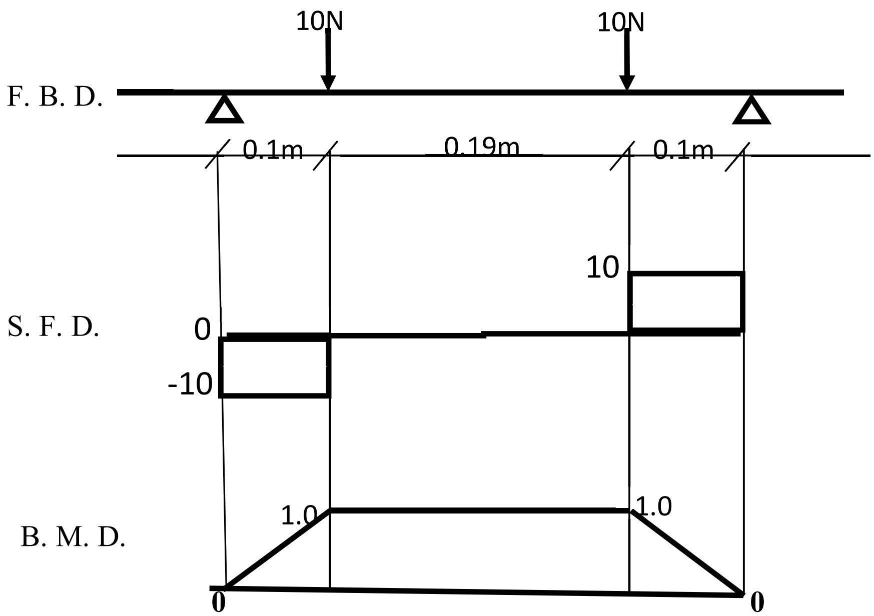

Fig. 10. Free body, shear force and bending moment diagrams of defibering shaft

2.3.8 Design for defibering chamber thickness

Defibering chamber thickness was obtained using Equations 10 and 11 given by Khurmi (2009).

$$T = \frac{P \, X \, d}{2\sigma t1 l X \eta} \tag{10}$$

$$P = \frac{F}{A} \tag{11}$$

where,

t is thickness of the cylindrical shell, mm
P is intensity of internal pressure, MPa
d is internal diameter of the cylindrical shell, mm
$\sigma t1$ is circumferential or hoop stress of the material of the cylindrical shell, MPa = 16 MPa.
l is length of the cylindrical shell, mm
η is efficiency of the joint (%) = 0.85
F is force on defibering chamber, N
A is area of defibering chamber, mm^2

$A = \frac{\pi d^2}{4}$

$A = \frac{3.142\ (10^2)}{4}$

$A = 78.6mm^2$

$P = \frac{3.4}{78.6}$

$P = 0.043\ N/mm^2$

P = 0.043 MPa

$t = \frac{0.043 \ X \ 200}{2 \ X \ 16 \ X \ 1.2 \ X \ 0.85}$

$t = \frac{8.6}{32.64}$

t = 0.3 mm
assume 1.5 mm

2.3.9 Design for supporting frame

The design of supporting frame was obtained using Equations12 and 13 given by Khurmi (2009).

$$\text{Bending moment (M)} = \frac{PL}{4} \quad (12)$$

$$\text{Maximum bending stress } (\sigma) = \frac{6PL}{bh^2} \quad (13)$$

where,
P is Point load, N
l is Length of frame, m
b is width of frame, m
h is height of frame, m

$M = \frac{20 \ x \ 0.98}{4} = 4.9\text{Nm}$

$\sigma = \frac{6 \ x \ 20 \ x \ 0.98}{0.31 \ x \ 0.6^2} = \frac{117.6}{0.1116} = 1{,}053.76 \text{ N/m}^2$

$\sigma = 1.05 \text{ kN/m}^2$

The allowable bending stress of mild steel being the supporting frame material (F_b) is 140 kN/m^2 and it is greater than the maximum bending stress (σ) on the supporting frame which is 1.05 kN/m^2.

2.3.10 Design for power transmission unit (Belt Drive)

Power transmission unit was determined using Equation 14 given by Krutz *et al.* (2001).

$$L = 2C + \Pi \frac{(D+d)}{2} + \frac{(D-d)^2}{4C} \quad (14)$$

where,
L is Length of of open belt, m
C is Centre distance between the pulleys, m
D is Diameter of the larger pulley, m
d is Diameter of the smaller pulley, m

$L = 2(0.47) + 3.142 \ \frac{(0.18+0.085)}{2} + \frac{(0.18-0.085)^2}{4(0.47)}$

L = 0.94 + 0.8326 + 0.0048

L = 1.78 m

2.4 Performance Test and Evaluation of the Machine

The machine was evaluated using a wet coconut husk obtained from a dehusking site. The coconut husks were cleaned and prepared for the test. The coconut husk was first soaked in water for 5 days to dissolve the salt content in the husk, and then 1389 g of coconut husk were fed through the hopper into the defibering chamber. The machine was operated by a 2.5 kW electric motor operating at an angular speed of 1260 rpm which was connected to the shaft on which beaters were mounted in the defibering chamber. During the evaluation process, the cocopeat $output_p$, cocofibre $output_c$, and processing time were recorded. The efficiency and capacity of the machine were determined from the data obtained. The test was replicated thrice. The mean results obtained from the performance test is presented in Table 1.

3. RESULTS AND DISCUSSION

Table 1. Results of the Testing of the Coconut Husk Fibre Separator

S/N	Input (g)	Cocopeat $Output_p$ (g)	Cocofibre $Output_c$ (g)	Time (sec)	Efficiency (%)	Capacity (kg/hr)
1	1389	369	789	44	83	94.68
2	1389	361	779	46	82	89.28
3	1389	311	831	64	82	64.08
Total	4167	1041	2399	154	247	246.04
Average	1389	347	798	51	82	82.68

Table 2. ANOVA on the three replicates

Variable	F-value	p-value	Interpretation
$Output_p$	7.87	0.057	Not significant at $\alpha = 0.05$
$Output_c$	1.68	0.274	Not significant
Efficiency	0.50	0.634	Not significant
Capacity	5.96	0.074	Not significant

The average output of cocopeat $output_p$ cocofibre $output_c$ and processing time were 347 g, 798 g and 51 s, respectively as presented in Table 1. The quantity of cocofibre obtained is higher than the cocopeat, which agreed with the report of Akhir (2015), that the ratio of coir fibre to coco peat in one coconut husk is 75:25. This demonstrate the ability of the machine to separate coco-peat and coir fiber from coconut husk. The processing time is shorter than that reported by Akhir (2015), which varied from 55 s to 94 s. The average efficiency and capacity of the machine are respectively, 82 % and 82.68 kg/hr. This is more time efficient and effective when compared with traditional method of separation.

One-way Analysis of variance (ANOVA) test was performed for each variable: $output_p$, $output_c$, efficiency and capacity. Table 2 is the results of the replicated test of the Coconut Husk Fibre Separator. It provides important insights into the machine's operational performance in terms of fibre output, coir output, efficiency, and processing capacity. From the analysis, the cocopeat output ($output_p$) across the three replicates had a mean of 347 grams with a moderate variation (standard deviation of approximately 31 grams). Although there was some fluctuation among replicates, the variation was not statistically significant at the 5% level. This suggests that the machine can produce a fairly consistent amount of cocopeat from a fixed input of coconut husk, even though slight operational differences or material heterogeneity may cause small variations.

Similarly, the cocofibre output ($output_c$) was relatively stable, averaging 798 grams with low variation (standard deviation of about 26 grams). The coefficient of variation for this component was the lowest among the variables, indicating that the separator consistently extracts fibre material from the input husks with minimal variability between replicates. In terms of efficiency, the machine demonstrated a high and stable performance, with an average efficiency of 82.33% across all three tests. The standard deviation was less than 1%, reinforcing the reliability of the separator in maintaining a consistent level of material separation efficiency. This suggests that the machine can effectively separate usable material from waste with minimal losses.

However, processing capacity—measured in kilograms per hour—showed the greatest variability. The mean capacity was about 82.68 kg/hr, but the standard deviation was relatively high (15.49 kg/hr), with a coefficient of variation nearing 19%. This variation can largely be attributed to differences in the time taken for each test, even though the input quantity was constant across replicates. For instance, a longer processing time in the third replicate resulted in lower hourly capacity. While the variation was not statistically significant, it does suggest that operational efficiency over time may be influenced by external factors such as machine speed regulation, operator handling, or husk texture. Thus, the Coconut Husk Fibre Separator demonstrates consistent performance in terms of output and efficiency, with relatively low variability. While capacity shows more fluctuation, this does not appear to significantly affect the reliability of the machine for practical use. The results suggest that the machine is well-suited for regular use in fibre separation tasks, with room for further refinement in process timing to optimize capacity.

4. CONCLUSION

The defibering machine was fabricated to separate coconut husk into cocopeat and cocofibre. Cocopeat is a useful product in the field of agriculture and in home nurseries. This is a new technique proposed for maintaining the growth of plants in potting medium. The coconut husk fiber separator can be used to process wet husks. It is very useful and economical for the coconut farmers to collect and process the coconut husks into higher value added products such as cocopeat and cocofiber. The average efficiency and capacity of the machine proved that the machine is more time efficient and more effective when compared with traditional method of coconut husks separation. The machine is well-suited for regular use in fibre separation tasks, with room for further refinement in process timing to optimize capacity. The estimated current production cost of the separator is ₦420,750.00k.

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