DEVELOPMENT OF A COIR FIBRE EXTRACTING MACHINE

[1]OMONIYI, Temidayo Emmanuel and [2]AYODELE, Emmanuel Bayo

[1,2]Department of Wood Products Engineering, University of Ibadan

---

Abstract: The traditional methods of extracting fibres from the coconut husks are extremely tedious and time-consuming and not suitable for large scale production. The objective of the study was to develop an efficient and effective, low-cost, coir fibre extracting machine from locally available resources. The machine consists of the hopper, crushing, sieving and the power transmission units, which were manufactured using standard manufacturing techniques. From the design analysis, a 6hp electric motor was required to drive the 0.00938m^3 hopper capacity machine to produce a torque of 11.8Nm at 3000rpm. The flat-belt required to transmit power from one pulley to the other was 1.5m long and had a groove angle of 17^0, and a torsional moment of 11.98Nm was acting on a shaft of diameter 30mm. Performance evaluation showed that the efficiency of the crushing unit and sieving units respectively ranged from 72 to 96% and 81.9 to 82.1% at 8.0% M.C. The average throughputs for the crushing and sieving units were; 14.5kg/hr and 13.9kg/hr respectively. The machine developed will serve as a time, labour and money saver in successful extraction of coir fibres for composite productions and other applications.

Keywords: Coir fibre, Fibre extracting process, Machine efficiency and throughput, Natural fibre composite

Introduction

Natural plant fibres can easily be sourced in many tropical countries and are available in large quantity all year round. These fibres are considered as environment friendly materials due to their biodegradability and renewable characteristics. Recently, the interest has turned over on utilizing the natural plant fibres such as bagasse, coir, and oil palm fibres as effectively and economically as possible to produce good quality fibre for various applications.

Production of natural fibre reinforced composite materials involves proper processing of fibres into the required dimensions and then introducing the matrix to form composites. This work is about extracting coir fibres from coconut husks and processing them to the required geometry for composite board production.

Of the numerous available natural fibres, coir fibre is one of the hardest that attracts a lot of difficulty in separating or reducing the fibre size for natural fibre composite production. Coconut fibres come mainly from the coir (Figure 1) [1]. The coir is the seed hair fibrous material found between the hard internal shell and the outer coat (known as the endocarp) or husk of a coconut. The matured coconut fibre is coarse, stiff and reddish brown in colour and it is made up of smaller threads, consists of lignin (a woody plant substance) and cellulose [2]. The coir fibre is useful for the production of matrix-bond composites [3]. Due to the stiff nature of the fibre, conventional technology is required to extract its fibres. The traditional production of fibres from the husks as described by [4] is a laborious and time-consuming process which highly pollutes water surfaces as observed by [5-6] and results in the accumulation of large dumps of pith. After manually separating the nut from the husk, the husks are processed by various retting techniques, and generally in ponds of brackish waters (for about 3 – 6 months) or in salt backwaters or lagoons. This requires 10 to 12 months of anaerobic (bacterial) fermentation. By retting, the fibres are softened and can be decorticated and extracted by beating [7], usually by hand. After hackling, washing and drying (in the shade) the fibres are loosened manually and cleaned. Alternatively, mechanical processing using either defibering or decorticating equipment can be used to process the husks after only five days of immersion in water tanks. By using revolving “drums” the coarse long fibres are separated from the short woody parts and the pith. The stronger fibres are washed, cleaned dried, hackled, and combed. The quality of the fibre is greatly affected by these procedures.

Size reduction is an important operation because it involves the breaking down of larger particles into smaller and required sizes as different types of composite materials require different fibre sizes for proper binding of the components. Milling, crushing and grinding are processes widely used in the composite industries to reduce fibre sizes due to the advantages of high productivity and flexibility in fibre size ratio they provide [8]. There are different types of size reduction equipment; these include the crushers and the grinders.

According to Doerksen [9], the efficient operation of size reduction equipment depends on the speed of rotation of the machine, the hammer mill and the screen design. The size reduction and sieving machine conventionally operates on the principles of impact and pulverization. It consists of a rotor assembly on which swinging hammer or beater that does the milling is mounted on and a screen that does the sieving. The rotor shaft of this crusher can be placed vertically or horizontally, however horizontal placement is preferred [10]. The existing size reduction machines are expensive and many are not incorporated with screen or sieves.

For more efficient processing of natural fibres for composite production and other possible applications and proper waste recycling, a technological improvement that can be of help is encouraged. Therefore, the objective of this work was to design, fabricate and evaluate the performance of a cost effective laboratory scale coir fibre extraction and sieving machine.

Fig. 1: Coconut Coir

Materials and Methods

Materials Collection and Preparation

The materials for the construction of the machine were majorly mild steel sourced locally from Bodija iron market and for the performance evaluation coconut husks were collected from Badagry area of Lagos state. The collected coconut husk were prepared and made ready for crushing by drying to moisture contents of 26, 16 and 8%.

Design Considerations

The product was meant to be cost effective, as a result, the availability, strength and durability of the local construction materials were the major properties considered in the design. Design considerations as outlined in standard machine design books were also taken into consideration. Data obtained from the preliminary investigations carried out on some physical and engineering properties of coconut husk were used to select design parameters.

Design Analysis

The design was carried out based on methodology given in machine design textbook [11] and literatures [12-14]. The design analysis was carried out to evaluate necessary design parameters for proper development of the machine. There are five mechanisms which facilitate proper functioning of sieving and milling machine. These mechanisms include:

i. Feeding Mechanism: This provides the passage for the materials to be processed into the crushing chamber
ii. Crushing mechanism: Crushing mechanism is the process responsible for breaking and retting of the coconut husks into fibres.
iii. Driver and driven mechanism: This is the source of rotating power to the shaft.
iv. Sieving and Screening mechanism: The device was designed to hold, sieves of different sizes, which is agitated to sieve the processed fibres into desired dimensions.
v. Collection mechanism: The sieved fibres are collected through an open duct into a sack.

Component Design and Calculations

Feeding Unit Capacity

The volume of the hopper is determined by:

$V = A\ H$ (1)

Where:

V = Volume of the hopper, (m^3)

A = Area of the hopper, (m^2)

H = Height of the hopper, m (H = 0.10 m)

But;

The total surface (A) of the trapezium shaped gate of the hopper is calculated from

$A = \frac{1}{2} \times (a + b) \times h$ (2)

Where: a, b and h are the upper length (200mm), lower length (360mm) and height (335mm) respectively.

Therefore:

$A = \frac{1}{2} \times (0.2 + 0.36) \times 0.335$

$A = 0.0938 m^2$

Therefore substitute the value into equation (1)

We have:

$V = A \times H$

$= 0.0938 \times 0.10 = 0.00938\ m^3$

Crushing Unit

The unit consists of cylindrical drum, designed based on the capacity of the machine which has a diameter d, of 350 mm, thickness t, of 3 mm, and the length of 200 mm.

Therefore the volume was determined as:

$V = A \times L$ (3)

Where;

V = Volume, m^3

A = Circular surface area of drum, m^2

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

L = length of drum, (0.2m)

Where;

$A = \frac{\pi \times 0.35^2}{4} = 0.096\ m^2$

Therefore;

$V = 0.096 \times 0.200 = 0.019\ m^3$

Curve Surface Area of the Drum was determined from;

$Ac_s = \pi rh,$ (5)

Where; r = radius $(\frac{d}{2}) = \frac{0.350}{2} = 0.175m$, h= 0.2m

$A_{cs} = \pi \times 0.175m \times 0.2m = 0.11m^2$

Drive Belt and Pulley System

According to Khurmi and Gupta [11], velocity ratio (V_r) of the belts drives is given by:

$$V_r = \frac{\text{Speed of last driven}(N_4)}{\text{Speed of first driver}(N_1)} = \frac{\text{Product of diameters of driver pulleys}}{\text{Product of diameters of driven pulleys}} \quad (6)$$

$$\text{Or } V_r = \frac{N_4}{N_1} = \frac{d_1 \times d_3}{d_2 \times d_4}$$

Where: d_1, = the electric motor pulley diameter, d_2 = the first belt driven pulley diameter d_3 = the second belt driver pulley diameter, d_4 = the driven pulley diameter

$d_1 = 120mm$, $d_2 = 60mm$, $d_3 = 40mm$, $d_4 = 140mm$, $N_1 = 3000rpm$

$$\therefore \ N_4 = \frac{d_1 \times d_3 \times N_1}{d_2 \times d_4}$$

$N_4 = 1714$ rpm

Length of the first belt drive was determined by,

$$L_1 = \frac{\pi}{2}(d_2 + d_1) + 2x_1 + \frac{(d_2 - d_1)^2}{4x_1} \quad (7)$$

x_1 = central distance (360mm)

$\therefore \ L_1 = 1005.1mm$

Length of the second belt drive was determined by,

$$L_2 = \frac{\pi}{2}(d_4 + d_3) + 2x_2 + \frac{(d_4 - d_3)^2}{4x_2} \quad (8)$$

x_2 = central distance (360mm)

$\therefore \ L_2 = 1009.5mm$, L=1500mm was chosen.

The belt with the following properties was selected from the Table of Indian standard (IS:2494-1974) according to Khurmi and Gupta [11], based on the calculated dimensions and power transmitted (3.7 Kw or 5hp).

Type of belt selected = Type A, Groove angle (2β) = 34°, and Coefficient of friction (μ) = 0.30

Pulleys Selection

From the table of standard dimensions of v-grooved pulley Khurmi and Gupta, [11] face width of the pulley is determined by,

$$B = (n - 1)e + 2f \qquad (9)$$

Where: n is the number of grooves in the pulley; e and f are standard dimensions (mm) in the v-grooved pulley. For 'type A' belt and single grooved pulley, n =1, e =15, f =10 $\therefore B = 20mm$

According to Okafor *et al* [15], torque acting on electric motor pulley is also given by:

$$T_m = \frac{(T_1 - T_2)d_1}{2} \qquad (10)$$

$$11.8 = \frac{(T_1 - T_2) \times 0.12}{2}$$

$$T_1 - T_2 = 196.67 \text{ N} \qquad (11)$$

Where: d_1 = the electric motor diameter, T_1 = the first belt tension in the tight side, and T_2 = the first belt tension in the slack side

Ratio of driving tension for the first belt is

$$2.3 \log\left(\frac{T_1}{T_2}\right) = \mu\theta_1 \operatorname{cosec} \beta \qquad (12)$$

Where θ_1= contact angle of belt determined from equation (13)

$$\theta_1 = 180° - 2\text{Sin}^{-1}\left(\frac{d_2 - d_1}{2x_1}\right) \qquad (13)$$

$$\theta_1 = 170.44° = 2.975 \text{ rad}$$

$$2.3 \log\left(\frac{T_1}{T_2}\right) = 0.3 \times 2.975 \times \operatorname{cosec}\left(\frac{34}{2}\right)$$

From which

$$\frac{T_1}{T_2} = 21.24 \qquad (14)$$

Solving equation (11) and (14) we have T_1 = 206.39 N and T_2 = 9.72 N

Velocity of the first belt drive given as

$$V_1 = \frac{\pi d_1 N_1}{60} = \frac{\pi d_2 N_2}{60} = 18.85 \text{ m/s} \qquad (15)$$

Power transmitted by the first belt drive is determined by,

$$P_1 = (T_1 - T_2)v_1 = 3707.2 \text{ Watt} \qquad (16)$$

Speed of driven pulley for the first belt (N_2) is the same as the speed of the driver pulley for the second belt (N_3),

$$N_2 = N_3 = \frac{d_1 N_1}{d_2} = 6000 \text{ rpm} \qquad (17)$$

Difference between the tension in tight side and slack side of the second belt is given by,

$$T_3 - T_4 = \frac{60 \times P_1}{\pi d_3 N_3} = 295 \text{ N} \qquad (18)$$

Angle of contact of the second belt, θ_2, on the driver pulley is given by:

$$\theta_2 = 180° - 2\text{Sin}^{-1}\left(\frac{d_4 - d_3}{2x_2}\right) \quad (19)$$

$\theta_2 = 164.03° = 2.863$ rad

Ratio of driving tension for the second belt is

$$2.3 \log\left(\frac{T_3}{T_4}\right) = \mu\theta_2 \text{cosec}\,\beta \quad (20)$$

$$2.3 \log\left(\frac{T_3}{T_4}\right) = 0.3 \times 2.863 \times \text{cosec}\left(\frac{34}{2}\right)$$

From which

$$\frac{T_3}{T_4} = 18.93 \quad (21)$$

Solving equation (18) and (21) we have $T_3 = 311.37$ N and $T_4 = 16.45$ N

Velocity of the second belt drive, V_2, given as

$$V_2 = \frac{\pi d_3 N_3}{60} = \frac{\pi d_4 N_4}{60} = 12.57 \text{ m/s} \quad (22)$$

Power transmitted by the second belt drive is determined by,

$$P_2 = (T_3 - T_4)v_2 = 3707.14 \text{ Watt} \quad (23)$$

Expression of the Force/Torque Needed to Shred the Coconut Husk (Coir)

The modulus of elasticity E was determined from the expression as given by Khurmi and Gupta [11] and Sakthivei and Ramesh, [16] as:

$$E = \frac{fl^3}{48yI} \quad (24)$$

Where: E is the modulus of elasticity; y is the deflection in mm; f is the shredding force/load in N; I is the moment of inertia and *l* is the length of material/coir fibre.

Rearranging we have

$$EI = \frac{fl^3}{48y} \quad (25)$$

Where, EI is the flexural rigidity of the coconut husk

Also,

$$I = \frac{BH^3}{12} \quad (26)$$

Where, I is the moment of Inertia; B is the breadth of coconut husk in mm; H is the height/thickness of coconut husk in mm.

Shaft Design

The design of shaft is based on combined shock and fatigue, bending and torsional moment. The diameter of the main shaft was determined by applying the formula as given by Khurmi and Gupta (2005)

$$d^3 = \frac{16}{\pi s_s}\sqrt{[K_b M_b]^2 + [K_t M_t]^2} \quad (27)$$

Where: d: Diameter of shaft, m, M_b: Resultant bending moment, Nm, M_t: Torsional moment, Nm, K_b: Combined shock and fatigue factor applied to bending moment, K_t: Combined shock and fatigue factor applied to torsional moment, S_S: Allowable shear stress of the shaft material, MN/m^2.

The values of K_b and K_t were taken as 1.5 and 1.0 respectively for the gradually applied load on the rotating shaft and the allowable shear stress of the shaft (Ss) as 40 MN/m^2 based on American Society of Mechanical Engineers (ASME) standards.

M_b was calculated by analysing moments due to vertical loading in bending moment diagrams of the shaft. M_t was calculated by the following equation:

$$M_t = \frac{P \times 60}{2\pi N} \quad (28)$$

Where P: Transmitted power, Watt, Using P = 3700 W and N = 3000 rpm, Mt was calculated as 11.78 Nm, Mb as 110.98 Nm.

By applying in the equation (10), shaft diameter of the main shaft (d) is 28 mm. For factor of safety shaft diameter of 30 mm is selected.

Electric Motor

According to Khurmi and Gupta [11], torque acting on electric motor pulley is determined by:

$$T_m = \frac{60 \times \text{rated power}}{2\pi N_1} \quad (29)$$

$$T_m = 11.8 \text{ Nm}$$

The electric motor was selected based on the torque and power (3.7kw) required to turning the pulleys. So an electric motor of a capacity of 5hp was selected.

Fabrication of the Machine

The machine parts were fabricated as designed at the maintenance department of the University of Ibadan, Ibadan Nigeria. The operations of cutting, grinding, welding, forming, etc. were performed during the fabrication process. The parts of the machine were assembled accordingly.

Cost Analysis

The cost of production was analysed.

Testing and Performance Evaluation of the Machine

The machine was tested with coconut husk (Figure 1) weighing 500grammes at three different moisture contents (%) and the performance was evaluated based on crushing and sieving efficiencies, capacity and throughput with five replications.

Determination of the Moisture Contents (%)

To determine the moisture content for each test sample, the initial weight (Wi) of the selected sample was recorded and then air dried. The final weight (Wf) was also recorded. The moisture contents of the two samples were determined using:

$$MC_{wb} = \frac{W_i - W_f}{W_f} \times 100 \quad (30)$$

Where:

MC_{wb} = Moisture content, % (Dry Basis)

W_i = Initial mass of the sample, kg and W_f = Final mass of the sample, kg

The efficiency, capacity and throughput for the milling and sieving units were evaluated using the following equations:

$$\text{Crushing Efficiency } C_{eff} = \frac{\text{mass of recovered material}}{\text{mass of input material}} \times 100\% \quad (31)$$

$$\text{Sieving Efficiency} = \frac{mass\ of\ material\ recovered\ after\ sieving}{total\ feed\ from\ crushing\ unit} \times 100\% \quad (32)$$

$$\text{Throughput of milling unit} = \frac{mass\ of\ sample\ before\ milling\ (kg)}{time\ taken\ for\ milling\ (hr)} \quad (33)$$

$$\text{Throughput of sieving unit} = \frac{mass\ of\ sample\ before\ sieving\ (kg)}{time\ taken\ for\ sieving\ (hr)} \quad (34)$$

Results and Discussions

The results for the machine components and specifications are as presented in Table 1.

Table 1: Components Designed and Specifications

S/No	Machine Components	Specifications
1	Hopper	Capacity: 0.00938m^3, material: Mild Steel of thickness t = 3mm
2	Crusher	Material: Mild steel; curve surface area = 0.11m^2
3	Shaft	Material: Carbon steel; Diameter: 30mm
4	Drive Belt	Material: Rubber; Type A, Groove angle (2β) = 34°, and Coefficient of friction (μ) = 0.30
5	Pulleys	Belt type A's Pulley; width = 20mm, Material: Cast Iron
6	Electric Motor	Capacity:6Hp
7	Sieving Unit (Shaker)	Oscillation 29Hz

The schematic view is as shown in Figure 2. The designed and fabricated components provided in Table 1 were assembled to produce the machine as shown in Figure 3.

Table 2: Cost Analysis

S/N	Materials	Specification	Quantity	Cost (₦)
1	Sheet metal (mild steel)	3 mm	1 sheet	9500
2	Angle iron	50 × 50 × 4 mm	1 length	7000
3	Bearing (pillow)	30 mm & 25 mm	2 pair	6600
4	Round rod	30 mm	3 ft. long	3500
5	Pulley (cast iron)			2000
6	Flat bar	50mm × 4mm		4500

7	Bolt and nut	M 19	1 dozen	650
8	Electrode	Gauge 12		800
9	Cutting disc	Flex vide		1000
10	Grinding disc	Power flex		500
11	Transportation			2500
12	Miscellaneous			7500
13	Workmanship			15000
14	Electric Motor	5Hp	1	15000
15	**Total Cost**			**76050 or $190**

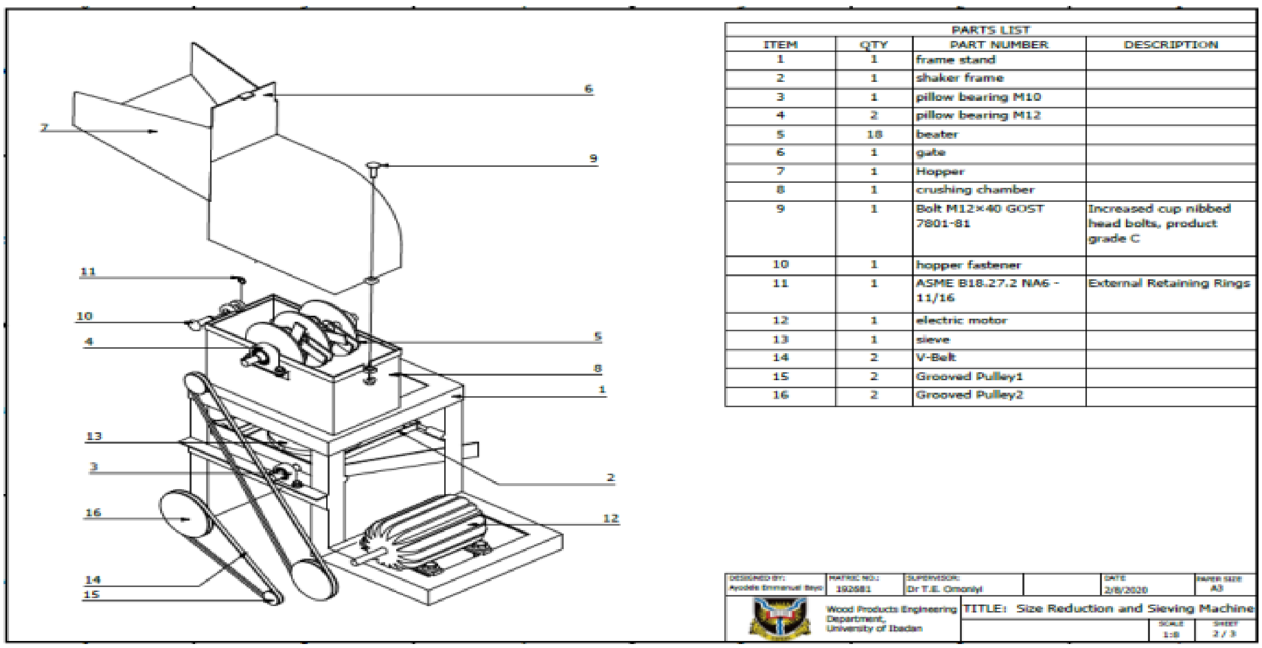

Fig. 2: A Sectional View of the Machine

List of parts of the Coir Fibre Extraction Machine

1 – Gate 2 – The hopper 3 – Crushing unit 4 – Pillow bearing 5 – Main shaft 6 – Driven pulley 7 – V-belt 8 – Electric motor 9 – Sieve 10 – Sieving unit (shaker) 11 – Collection unit 12 – Frame stand

Fig 3: Coir Fibre Extraction and Sieving Machine

Table 3: Results for the Performance Evaluation of the Machine for a Period of 120 Seconds

Fibre Types	Moisture Content (%)	Mass (g) Charged	Mass (g) after Crushing	Mass (g) after Sieving	Crushing Efficiency (%)	Sieving Efficiency (%)	Crushing Throughput (kg/hr)	Sieving Throughput (kg/hr)
	26	500	360	295	72	81.9	14.5	10.5
Coconut Husk	16	500	450	369	90	82	14.5	13.1
	8	500	480	394	96	82.1	14.5	13.9

Fig. 4: Processed Coconut Coir Fibres

The total production cost of $190 (₦76,050.00) was estimated for the machine as presented in Table 2. This value makes the local production of the machine cost effective as the imported and sophisticated one will be highly expensive and will be difficult to obtain for laboratory use here in Nigeria, a developing nation. The machine was used to extract coconut coir fibres (Figure 4). Table 3 presented the results obtained from the performance evaluation of the size reduction and sieving machine designed and produced. The results showed that as the moisture content (M.C) of the test samples decreased from 26% down to 8%, the efficiency of the machine increased. This followed the trend as confirmed by Hamid [17]. As presented in Figure 5, the machine performed best with the coir fibre at 8% M.C recording 96% efficiency, while the worst performance efficiency was recorded for the machine with the coir fibre at 26% M.C when it was able to reduce only 72%. As expected the changes in the efficiencies of the sieving unit were insignificant at 82% this may be due to the fact that the same screen of size 2.5mm was used for all the samples at the different M.C. the output capacity (kg/hr.) for the milling/crushing unit which is also the throughput (kg/hr.) for the sieving unit increased from 10.5kg/hr. to 13.9kg/hr as the moisture contents decreased from 26% to 8% for the coir fibre.

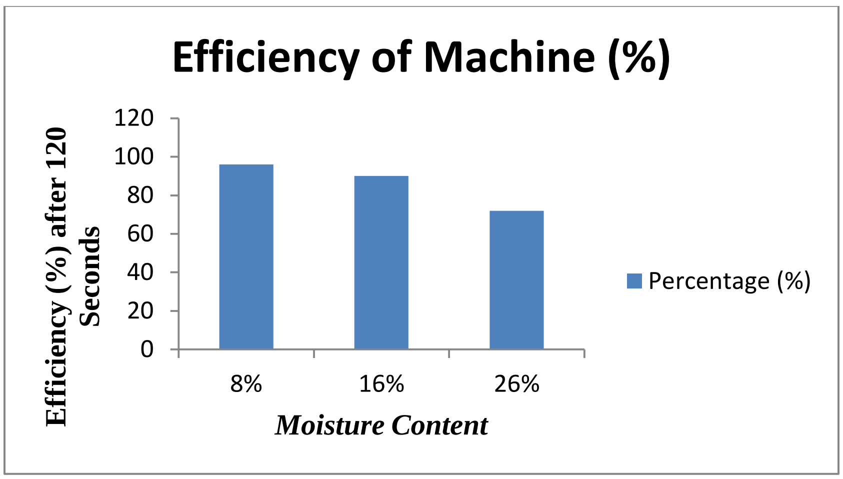

Fig. 5: Efficiency of machine at 26%, 16% and 8% Moisture Contents

Conclusion

A laboratory scale coir fibre extraction machine had been developed and its performance evaluated. It was observed that the machine was cost effective compared to imported machine of similar specification. The performance of the machine was dependent on the moisture contents of the fibre as the efficiency increased with a decrease in the moisture contents. The efficiency of the machine at a moisture content of 8% was observed to be 96% over a period of 120 seconds; this implies that the machine served greatly as a time and labour saver. The fibres produced are suitable as sound absorption and insulating materials, packaging products and for composite production.

References

[1] Sapuan, S.M. (2014). Tropical Natural Fibre Composites; Properties, Manufacture and Applications. Selangor, Malaysia: Springer.

[2] Lai, C.Y., Sapuan, S.M., Ahmad, M., Yahya, N., Dahlan, K.Z.H.M. (2005): Mechanical and electrical properties of coconut coir fibre-reinforced polypropylene composites. Polym. Plast. Technol. Eng. 44, 619 – 632.

[3] Ahmed, E., Da, K. A., and Hannan, O. M. (2016). Particle board from coir pith, Bangladesh Journal of Science and Industrial Research 51(3):239

[4] Woodroof, J.G. (1970). Coconuts: Production, Processing and Products. AVI, Westport CN

[5] Abbasi, S.A and Nipaney, P.C (1993). Environmental impact of retting of coconut husk and directions for the development of alternative retting technology, Pollut. Res. 12, 117-118.

[6] Umayorubhagan, V., Albert G.M.I., and Ray, C.I.S. (1995). Physico-chemical analysis of the water of Pottakulam Lake at Thengapattanam in Kanyakumari district (Tamil Nadu), Asian J. chem Rev 6, 7-12

[7] Banks, W., and Hall, F.J., (1964) Process for decortication of coconuts, Br. Patent no. 29249

[8] Chuanzhong X., Liying C., Pie w., Yanhua M., Ding H. (2012). Developed on a Hammer Mill with separate sieving Device, TELKOMNIKA Indonesian Journal of Electrical Engineering Vol.10, No. 6, October 2012, pp. 1151-1156

[9] Doerksen R., (1993). Product reduction, hammermill, dry and steam rolling, Fifteenth Canadian feed technology course, Landmark, Manitoba

[10] Nwaigwe, N. K., and Nzediegwu, C. (2012). Design, Construction and performance Evaluation of a Modified Cassava Milling Machine Journal of Applied Science, Engineering and Technology 4(18): 3354-3362.

[11] Khurmi, R. S., and Gupta, J. K. (2005). A textbook of machine design (1st ed.). Ram Narga, New Delhi: Eurasia publishing house (PVT.) LTD.

[12] Naik, K., Swamy, R.P., and Naik, P. (2014). Design and Fabrication of Areca Extraction Machine, International Journal of Emerging Technology and Advanced Engineering 4(7), 860-866

[13] Oreko, B.U., Okiy, S., Emagbetere, E., and Okwu, M. (2018). Design and Development of Plantain Fibre Extraction Machine, Nigerian Journal of Technology (NIJOTECH) 37(2), 397-406.

[14] Rahamaththulla, S., Premnath, S., Ravi, V., Madheswaran, S., and Jayakumar, N. (2018). International Journal for Scientific Research & Development vol.6 Issue 01, 390-393

[15] Okafor, E.C., Ihueze, C.C., and Nwigbo, S.C. (2013) Optimization of Hardness strengths Response of Plantain Fibres Reinforced Polyester Matrix Composites (PFRP) Applying Taguchi Robust Design. International Journal of Engineering 26(1) 1-12.

[16] Sakthivei, M. and Ramesh, S. (2013). Mechanical Properties of Natural Fibres (Plantain, Coir, Sisal) Polymer Composites, Science Park, 1, 1-6.

[17] A. Hamid, (2015). Design and Performance of a Mobile Coconut Husk Fibre Separator (Unpublished), Pp 1 – 13.