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From Editor's Desk

Dear Researcher,

Greetings!

Research article in this issue discusses about development of a Coconut Dehusking Machine.

Let us review research around the world this month; South Korean scientists have created a temperature cycle for the on-chip flow-through polymerase chain reaction (PCR) using a single heater. Tom Brown, an expert in nucleic acid chemistry at the University of Southampton, UK, says that a po table PCR device could find widespread use. 'Portable PCR devices could be used in important applications in human and veterinary medicine for point of care analysis, and in forensic science for identification.

Looping fibre optics from Japan under the Arctic ice will improve internet performance – but is easier said than done. The retreat of sea ice is bringing 21st-century communications to the Arctic. In mid-August, construction should start on the first submarine fibre-optic cables to cross the Arctic Ocean, providing digital shortcuts between London and Tokyo, Japan.

Struggling to make your smart phone battery last the whole day? Paying for your apps might help. Up to 75 per cent of the energy used by free versions of Android apps is spent serving up ads or tracking and uploading user data: running just one app could drain your battery in around 90 minutes.

A fuel cell powered by naturally occurring bacteria has successfully converted 13 per cent of the energy in sewage to electricity – and cleaned the waste water at the same time. It's hoped genetic engineering could make this much more efficient.

It has been an absolute pleasure to present you articles that you wish to read. We look forward to many more new technology-related research articles from you and your friends. We are anxiously awaiting the rich and thorough research papers that have been prepared by our authors for the next issue.

Thanks,
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Contents

Development of a Coconut Dehusking Machine for Rural Small Scale Farm Holders

B. N. Nwankwojike, O. Onuba, U. Ogbonna
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Abstract
A coconut dehusking machine comprising of two rollers with spikes, screw conveyor, barrier plates, conveyor belt, two spur gears and a handle was developed for small scale production in the rural areas. Performance test analysis conducted shows that the machine dehusks coconut fruits without nut breakage and distortion of the extracted fibre length and also that its average dehusking efficiency and capacity are 93.45% and 79 coconuts per hour. All materials used in the fabrication of this machine are of standard specifications and locally sourced. The estimated cost of producing one unit of the machine is thirty five thousand, six hundred and sixty-five naira (₦35,665.00). The machine also eliminated dependency on the epileptic public electric power supply in our rural areas which constitutes the major obstacle in the use of other mechanized coconut dehusking equipment in the rural areas.

Key Words: Coconut, dehusking machine, dehusking capacity, efficiency, small scale farmers,

I. INTRODUCTION

Coconut (cocos nucifera) is one of the world most useful and important perennial plants [1]. An individual coconut fruit shown in Figure 1 is made up of an outer exocarp, a thick fibrous fruit coat known as husk; underneath is the hard protective endocarp or shell [2].

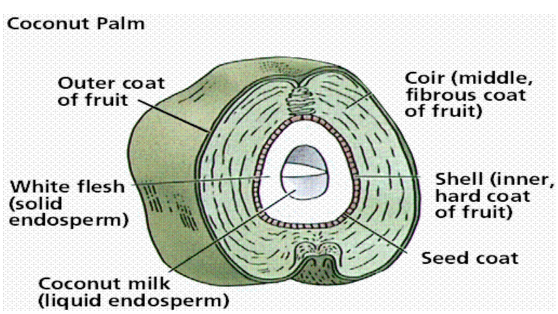

Figure 1: Structure of a coconut fruit

The nut varies from 147 to196mm in diameter and 245 to 294mm long. Three sunken holes of softer tissue called "eyes" are at one end of the nut. Inside the shell is a thin, white, fleshy layer, about 12.25mm thick at maturity, known as the "coconut meat". The interior of the nut is hollow and partially filled with a watery liquid called "coconut milk". The meat is soft and jelly-like when immature and becomes firm at maturity. The coconut milk is abundant in unripe fruits but it is gradually absorbed as ripening proceeds [3]. According to [4], the meat of 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. Coconut milk is a refreshing and nutritious drink while its oil is use for cooking and making margarine. Coconut oil is also very important in soap production. The shell is used for fuel purpose, shell gasifier as an alternate source of heat energy. The husk yields fibres used in the manufacture of coir products such as coir carpets, coir geo-textile, coir composite, coir safety belts, coir boards, coir asbestos and coir pith [5].

Although coconut is of immense economic importance to both the industrialist and rural dwellers, separation of its husk from the nut (dehusking) constitutes the first, most difficult and dangerous operation in its processing. The use of cutlass which is the popular traditional method for coconut dehusking poses threat and danger to the life of people involved, since on the process of dehusking, some cut their hands, and face as the cutlass usually bounces back on hitting the husk [6]. The use of metal spike was later developed to overcome these negative features of dehusking of the fruit with matchet but this later development focused only on extraction of coconut meat even though accident, time and energy consumption was reduced [3]. The search for a device that will enable effective recovery of other products of this fruit such as the milk, shell and fibre continued due to the importance of these coconut by-products in modern technological applications. Thus, a coconut dehusking machine was developed in Malaysia in 1986 [7]. Although this machine separates husk and the nut, thereby facilitates effective recovery of the fruits meat, milk and shell, its major problems of nut breakage and high cost of production and maintenance hinders its popularity. As a solution to the problem of nut breakage associated with this machine, [7], developed another with a dehusking capacity of 480 coconut fruit per hour. However, this later invention and other innovation that followed up till now usually come and go with problem of distorting the length of the husk (coir fibre) extracted.

Nowadays, the use of natural fibre reinforced composite is gaining popularity in automotive, cosmetic and plastic rubber applications because it offers an economical and environmental advantage over traditional organic reinforcements and fillers [8] and [9]. The features of coir fibre from coconut husk such as durability, relatively water-proof and resistance to damage by salt water and microbial degradation makes it popular in fibre reinforced composite applications. Ref. [8], also revealed that both fibre length and fibre orientation distribution play very important role in its mechanical properties; increase in length of coir fibre, increases the flexibility of the composite product like seat cushions for automobiles. Thus, there is need for machines that can extract coconut husk/fibre without distorting its length.

The unreliability and irregularity of public electricity supply especially rural areas of Nigeria is not likely to be solved in the near future due to long neglect the nations power sector which caused inadequate functional generating units/equipments in our national power stations [10]. However, rural small scale farmers constitutes the major source of coconut fruits to the nation and the budget of this category of farmers cannot carry the huge investment requirement in both electric generator and costly motorized coconut dehusking equipment which are mostly of foreign origin. Also, the problem scarcity of petroleum based fuels such as petrol and diesel in this country since 1993 makes the operation of this electric powered equipment difficult. Thus, most Nigerian coconut farmer still use the crude method of dehusking by cutting with cutlass despite the adverse features of this technique. It is therefore of economic sense if a manually operated machine that can dehusk the fruit without nut breakage and distortion of the extracted fibre length is developed from standard and locally sourced materials to ensure affordability to rural based small scale coconut farmer of this nation and other developing nations in both acquisition and maintenance. Hence, objective of this study is to develop a coconut dehusking machine that can dehusk the fruit without nut breakage and distortion of the extracted fibre length for rural small scale farm-holders.

II. MATERIALS AND METHODS

Machine Description

The major components of the developed coconut dehusking machine shown in Figure 2 are frame, dehusking unit, conveying unit, barrier plates/clearer, handle and bearing housing.

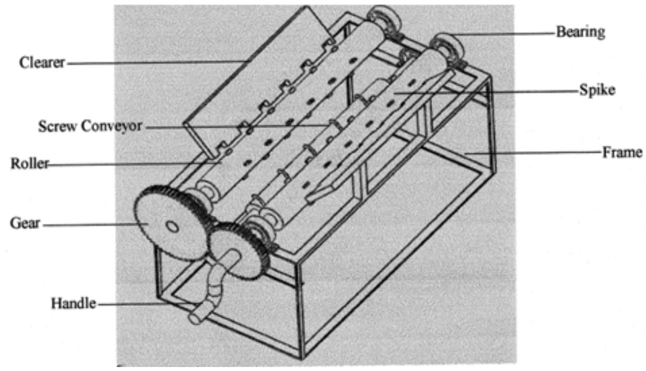

Figure 2: Diagram of the developed coconut dehusking machine

The frame is the main supporting structure upon which other components of this machine were mounted. The frame is a welded structure constructed from 50x50x5mm angle iron with dimensions of 920mm length, 480mm width and 400mm height. The dehusking unit comprises of two rollers, two roller shafts and two spur gears. Each roller was formed by welding thirty-two metal spikes (2 x 20 x 5mm) on an 80mm diameter mild steel pipe mounted on a roller shaft. Each of the roller shafts is a mild steel rod of 55mm diameter and 920mm long supported at both ends by ball bearings with a gear mounted at right ends. Also mounted at the right end of the driving roller shaft is the driving handle while driven roller shaft drives the conveying unit of the machine through a driving pulley mounted on it.

The conveying unit consists of a screw conveyor, shaft, two clearers, pulley and belt. The screw conveyor was formed by scrolling and welding a 10mm diameter mild steel rod on a 75mm diameter mild steel pipe with a pitch of 92mm. The conveyor shaft is a mild steel rod of 30mm diameter and 920mm long supported at both ends with ball bearing. The conveyor shaft is driven by a v-belt pulley of 100mm diameter which runs at the same speed with the low speed roller (57 teeth gear). The clearer was constructed by cutting u-notches on one edge of a mild steel plate of 2mm thickness. The clearers were fastened on the frame adjacent to the rollers. The developed coconut dehusking machine is very easy to operate and requires one operator. When the handle is wound, the rollers with spikes rotate in opposite directions towards the centre causing both the gripping and tearing of husk of coconut fruit placed in between the rollers. While the rollers rotate, a screw conveyor mounted between them 70mm below rotate in the same direction and speed as the driven roller with the help of a pulley-belt system to ensure proper discharging of dehusked nuts.

Design Analysis of the Machine

Design considerations:

The coconut dehusking machine was developed based on the following considerations:

1. The availability of materials locally to reduce cost of production and maintenance of the machine.
2. The screw conveyor was introduced in between and below the rollers for effective twisting of the coconut fruit during dehusking process and also for proper discharging of dehusked nut.
3. The size of the fruit reduces as the husk is progressively removed, thus, the space between the rollers was gradually tapered by increasing the projections of the spikes from the right to left end of the machine to enable effective gripping of the fruits nut as the husk is been removed.
4. It is desired that the coconut fruits should be well dehusked without nut breakage and also that length of the husk/coir fibre extracted should not be distorted, thus, rectangular-shaped spikes were used while gears and pulleys were carefully designed/selected to meet the required synchronized speeds of the dehusking and conveying units.

Selection of gears, pulleys and determination of their speeds and belt tensions:

The machine requires two gears, two pulleys and a belt for its drives. Standard spur gears (steel) with 20^{0} pressure angle each were selected due to simplicity in design, availability/economy of maintenance, absence of end thrust on bearing and suitability for heavy loads features of this type of gear. The driving gear has 42 teeth, addendum and pitch circle diameter of 188mm and 160mm respectively while number of teeth, addendum and pitch circle diameters of the driven gear are 57, 248mm and 220mm respectively. The pinion and the handle were mounted on the driving roller shaft while the driven roller carries the 57 teeth gear. Due to its availability, durability, cost and performance, mild steel pulleys with groove angle of 38^{0} each were selected. The driving pulley was mounted on the driven roller shaft and the driven on the conveyor shaft. Each of the pulleys has a diameter of 100mm, thus, the shafts of driven roller and screw conveyor run at the same speed and this speed was determined as 14.74rpm using the relation;

$$N_1 T_1 = N_2 T_2 \qquad (1)$$

Where: N_1 is the speed of the driving gear = 20rpm

N_2 is the speed of the driven gear, rpm

T_1 is number of teeth on the driving gear

T_2 is number of teeth on the driven gear

The centre distance, *C* between the adjacent pulleys was computed as 150mm using Equation (2) [11].

$$C = \frac{1.5D_2}{VR^{1/3}} \qquad (2)$$

Where *VR* is the speed ratio of this drive and D_2 is the diameter of the driven pulley. Thus, length of the belt, *l* was computed as 614mm from expression given by [12] as;

$$l = 2C + 1.57(D_2 + D_1) + \frac{(D_2 - D_1)}{4C} \qquad (3)$$

where D_1 is the diameter of the pulley on the driven roller (secondary driver). Type "A" v-belt is suitable for this drive since the drive transmits less than 3.75kW. Based on [13], a v-belt with standard pitch length, mass per unit length, maximum safe stress and cross sectional area of 645mm, 0.173kg/m, 2.1N/mm^2 and 81mm^2 was selected for the drive. Consequently, the exact centre distance between the pulleys, angle of lap of the belt on the pulley and belt speed used in the fabrication of the machine were determined as 165.5mm, 3.14rad and 0.077m/s using Equations (2), (3) and (4) respectively in accordance with [11].

$$\theta = 180 - \left[\sin^{-1}\left(\frac{D_2 - D_1}{2C}\right)\right] \qquad (4)$$

$$v_b = \frac{n_2 \pi D_2}{60} \qquad (5)$$

Where: θ = Angles of lap of the drive, rad.

v_b = Belt speed, m/s

n_2 = Speed of the driven pulley, rpm

In addition, maximum, centrifugal, tight side and slack side tensions of the belt were sequentially computed as 170.1N, 0.00103N, 170.098N and 9.4N respectively from the following relations by [11];

$$T_{max} = \delta a \qquad (6)$$

$$T_c = m v_b^2 \qquad (7)$$

$$T_i = T_{max} - T_c \qquad (8)$$

$$2.3\log\frac{T_i}{T_j} = \mu\theta \operatorname{cosec}\beta \qquad (9)$$

Where: T_{max} = Maximum tension of the belts, N

a = cross sectional area of the belts, mm

δ = Maximum safe stress of the belt, N/mm^2

T_c = Centrifugal tension of the belt, N

T_i = Tight side belt tensions, N

T_j = Slack side belt tensions, N

β = Groove angle of the pulley

μ = coefficient of friction between the pulley and belt

Determination shaft diameters:

The diameter, d for each of the three shafts of this machine was determined using maximum stress relations given by [11] and [12] as;

$$d = \left[\frac{16}{\pi\tau}\left(\sqrt{(k_b M_b)^2 + (k_t M_t)^2}\right)\right]^{1/3} \qquad (10)$$

where ;

τ = Allowable shear stress for steel shaft with provision for key ways = 42N/mm^2

M_t = Maximum twisting moment on the shafts, N-mm

M_b = Maximum bending moment on the shaft, N-mm

k_b = Combined shock and fatigue for bending

k_t = Combined shock and fatigue factor for twisting.

The maximum twisting moments on the driving and driven roller shafts, M_{tr} and that of the conveyor shaft, M_{tc} were determined as 323200N-mm, 444400N-mm and 8035N-mm respectively using Equations (11) and (12).

$$M_{tc} = \frac{FD_g}{2} \qquad (11)$$

$$M_{tc} = (T_i - T_j)\frac{D_2}{2} \qquad (12)$$

Where D_g is the pitch circle diameter of the gears while *F*, the torsional moment force on the gears/gear shafts was determined as 4040N using Equation (13) given by [13] as;

$$F = \tau A \qquad (13)$$

Where *A*, the average area of the spikes that penetrate into the fruit husk at the same time during dehusking process was determined as 40mm^2 while the shear yield strength, τ_{yt} of coconut fruit was determined as 100.98N/mm^2 using Equation (14) given by [14] as;

$$\tau_{yt} = 0.577\delta_{yt} \qquad (14)$$

Where δ_{yt} is tensile yield strength of coconut fruit given by [15] as 175N/mm^2. Bending moments occur on the shafts as a result of applied loads and belt tension, thus the maximum bending moment on the shafts were determined as follows;

Driving Roller shaft: The driving roller shaft and the forces acting on it are shown in Figure 3.

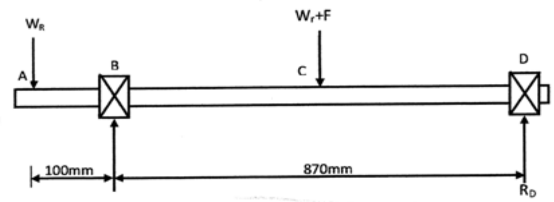

Figure 3: Driving roller shaft showing the applied forces on it.

Where W_r is weight of roller/spikes = 54N

The resultant load on this shaft due to the pinion, W_R was determined as 4310.56N from the expression given by [12] as;

$$W_R = \left[W_n^2 + W_G^2 + 2W_n + W_G \cos\phi\right]^{1/2} \qquad (15)$$

where: W_G is weight of the gear = 12N

ϕ is pressure angle of the gear

W_n is the normal load = 4299.28N

The normal load was computed from Equation (16) [12].

$$W_n = \frac{F}{\cos\phi} \qquad (16)$$

The reactions of bearings, R_B and R_D were determined by taking moment about B.

•M_B = 0; R_D (870) +4310.56(100) = 4094(435)

R_D = 1551.53N

Also •F_Y = 0; 1551.53 + R_B = 4094 + 4310.56

R_B = 6853.03N

Thus, the bending moments on this shaft are as follows;

B.M. at A and D = 0N-mm

B.M. at B = 431056N-mm

B.M. at C = 674918.45N-mm

Therefore, the maximum bending moment on this shaft is 674918.45Nmm. The dehusking of the coconut fruit by the driving roller is partially sudden with minor shock at the start of each operation and gradual as the process progresses, hence, K_b =1.5 and K_t =1.5 [11]. Hence, the minimum diameter of this shaft was determined as 51.44mm using Equation (10). Thus, a standard solid mild steel shaft of 55mm in diameter was selected for this machine's driving roller shaft.

Driven Roller shaft: The weight of the driven gear mounted on this shaft is 18N, thus, the resultant load on this shaft due to this gear, W_R was computed as 4316.2N using Equation (15). The maximum bending moment on this shaft was determined with the aid of Figure 4 as follows;

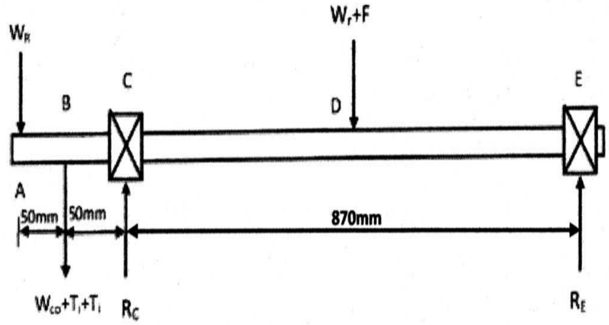

Figure 4: The driven roller shaft showing the applied forces.

Where: W_r is weight of the roller/spikes = 54N

W_{CP} is weight of the conveyor pulley = 5.2N

The reactions of bearings, R_C and R_E were determined by taking moment about C.

$\bullet M_C = 0$; R_E (870) +184.7(50) +4316.2(100)= 4094(435)

R_E = 1540.27N

Also $\bullet F_Y = 0$; 1540.27 + R_C = 4094 + 4316.2+184.70

R_C = 7054.63N

Thus, the bending moments on this shaft are as follows;

B.M. at A and E = 0N-mm

B.M. at B = 215810N-mm

B.M. at C = 440855N-mm

B.M. at D = 670017.55N-mm

Therefore, the maximum bending moment on the driven roller shaft is 670017.55Nmm. Also, the dehusking of the coconut fruit by the driving roller is partially sudden with minor shock at the start of each operation and gradual as the process progresses, hence, K_b =1.5 and K_t =1.5 [11]. The minimum diameter required of this driven shaft was determined as 52.68mm using Equation (10). Thus, a standard 55mm diameter solid mild steel shaft was also selected as the driven roller shaft of this machine.

Conveyor shaft: The details of forces acting on the conveyor shaft are shown in Figure 5.

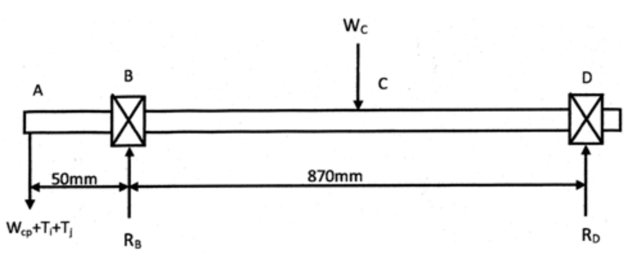

Figure 5: Conveyor shaft showing forces acting on it

Where:

W_C is weight of the conveyor shaft/its auger = 45N

W_{CP} is weight of pulley on the conveyor shaft = 5.2N

The reactions of bearings, R_B and R_D were determined by taking moment about B.

$\bullet M_B = 0$; R_D (870) +184.7(50) = 45(435); R_D = 11.89N

Also $\bullet F_Y = 0$; 11.89 + R_B = 45 + 184.70;R_B = 217.81N

Thus, the bending moments (*B.M.*) on this shaft were computed as follows;

B.M. at A and D = 0N-mm

B.M. at B = 92350N-mm

B.M. at C = 51670.85N-mm

Thus, the maximum bending moment on the conveyor shaft is 92350Nmm. The twisting and conveying of coconut fruit by the auger during as the fruit is been dehusked is sudden with minor shocks, hence, K_b = 2 and K_t =1.5 [12]. The minimum diameter of this conveyor shaft was determined from Equation (10) as 28.21mm. Therefore, a standard 30mm diameter solid mild steel shaft was selected for the conveyor shaft.

Power Requirement:

The power, *P* required for dehusking of one coconut by this machine was determined as 674.68W from the following relation given by [12] as;

$$P = Fv_d \qquad (17)$$

v_d is the speed of the driving roller = 0.167m/s. This speed was determined from relation given by [11] as:

$$v_d = \frac{N_1 \pi D_{g1}}{60} \qquad (18)$$

where D_{g1} is pitch diameter of the driving gear

Performance Evaluation Procedure:

In order to actualize the aims of this project, the dehusking capacity and efficiency of the coconut dehusking machine were evaluated using twenty experimental runs after its fabrication. Each test involved operating the machine by a different operator and recording of the total number of fruits, N_T each of the twenty operators dehusked in a given time. The dehusking process as per each operator was timed with a stop-watch. Also determined in each test are number of well dehusked nuts without distortion on the length of the husk extract, N_{gf} and number of well dehusked nuts with distorted husk extract, N_{dt}. Thereafter, the efficiency, η and capacity, *C* of the machine were computed in each case using the following relations:

$$\eta(\%) = \frac{N_{gf}}{N_T} \times \frac{100}{1} \qquad (19)$$

$$C\,(Fruits/h) = \frac{N_T}{t} \qquad (20)$$

III. RESULTS AND DISCUSSION

The results of the performance test (Table 1) show that the machine performed above 90% efficiency in all the tests cases as expected. It is also obvious from this table that the capacity of the developed machine ranges between 77 and 81 nuts per hour depending on the operator, however, on average an operator dehusks 79 nuts per hour with this machine.

Table 1: Result of the Performance Evaluation of Coconut Dehusking Machine

S/No.	Number of fruits dehusked	Number of well dehusked fruits	Number of fruits not dehusked well	Time (seconds)	Efficiency (%)	Capacity (Fruits/h)
1	26	24	2	1215.58	92.31	77
2	25	23	2	1153.85	92.00	78
3	27	25	2	1278.95	92.59	76
4	26	24	2	1184.81	92.30	79
5	25	24	1	1111.11	96.00	81
6	25	23	2	1168.83	92.00	77
7	27	25	2	1246.15	92.59	78
8	26	24	2	1200.00	92.31	78
9	26	24	2	1184.81	92.31	79
10	27	26	1	1215.00	96.30	80
11	25	24	1	1125.00	96.00	80
12	26	24	2	1155.56	92.31	81
13	26	24	2	1184.81	92.30	79
14	27	25	2	1246.15	92.59	78
15	25	24	1	1139.24	96.00	79
16	26	24	2	1170.00	92.31	80
17	27	26	1	1200.00	96.30	81
18	25	24	1	1139.24	96.00	79
19	26	24	2	1215.58	92.31	77
20	27	25	2	1230.38	92.59	79
Average					**93.45**	**79**

This machine was fabricated with standard and locally sourced materials and its estimated cost is thirty-five thousand, six hundred and sixty-five naira (₦35,665.00), thus, the machine is affordable to small scale farmers and maintainable.

IV. CONCLUSION

A coconut dehusking machine which dehusks coconuts without nut breakage and distortion of the extracted husks was developed at Michael Okpara University of Agriculture, Umudike for small scale farm holders in the rural areas. The machine is easy to operate and performs with an average dehusking efficiency and capacity of 93.45% and 79 nuts per hour. Introduction of this machine eliminates the problem of extracted coir fibre length distortion associated with the use of some mechanized equipment as well as drudgery and risks involved in the use of cutlass and spike for coconut dehusking. It also eliminates dependency on the epileptic public electric power supply in our rural areas.

References

[1] Ohler, J .G., and S. S. Magat. Cocos nucifera L.in Van der vossen H.A.M. and Umali B.E. edited. *Plant Resources of South-East Asia 14. Vegetable oils and fats.* Prosea Foundation, Bogor, Indonesia, 2002.

[2] Foale, M.A. The Coconut Palm. In: Chopra, V.L. and Peter K.V. edited *Handbook of Industrial Crops*. Haworth Press, New York, 2005.

[3] APCC. Coconut Food Process – Coconut Processing Technology.*Informantion Document.* Arancon, Jr, R.N., ed. Asian and Pacific Coconut Community. Jakarta, Indonesia,1996.

[4] Tilledaratne, H.A. Processing of Coconut Products in Sri Lanka. Asian and Pacific Coconut *Informantion Document.* Arancon, Jr., R.N., ed. Asian and Pacific Coconut Community. Jakarta, Indonesia. 1995.

[5] Thampan, P.K. *Handbook on Coconut Palm.* Oxford & IBH Publishing Co., New Delhi. 1996.

[6] Ohler, J.G.. Coconut, Tree of Life. *FAO Plant Production and Protection Paper 57.* FAO, Rome, Italy, 1984.

[7] Chandra D. Coconut Dehusking Machine. *Caribbean Industrial Research Institute (CARIRI) US4708056*, 1987.

[8] Franco, P.J.H. and Gonzalez, A.V. Mechanical Properties of Continuous Natural Fibre-Reinforced Polymer Composites. *Comp. Part A: App. Sci. Manuf., Vol. 35,* pp. 339-345, 2004.

[9] Balzer, P.S., Vicente, L.L., Briesemeister, R., Becker, D., Sordi, V., Rodold, A. Jr and Feltran, M.B. Study of the Mechanical Properties of PVC/Banana. *Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS) 2 (2):* 231-234, 2007.

[10] Anih. L. U. “Electric Power Generation in Nigeria” in Agunwamba J. C.and Eze-Uzoamaka O. J. edited *Introduction to Engineering.* De- Adroit Innovation, Enugu,Nigeria, pp.177-186, 2008.

[11] Sharma, P.C. and Aggarwal, D.K. *Machine Design.* S.K. Kataria and Sons, Nai Sarak Dechi. Katra books @yahoo.com, 2006.

[12] Khurmi, R.S. and Gupta, J.K.. *A Textbook of Machine Design (S.I. Units),* Eurasia publishing House (PVT) Ltd., Ram Nagar, New Delhi-11005s, 2005

[13] IS 2494-1974. *Indian Standards.* Indian Standards Institute, New Delhi, 1974.

[14] Rajput, R.K. *Strength of Materials*, S. Chand & Company Ltd, Ram Nagar, New Delhi, 2006.

[15] PCA-CETC. *Coconut Processing Technology Manual of Procedures.* Coconut Extension Training Centre, Davao City, Philippines, 1997.


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