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DEVELOPMENT OF A PALM NUT AND FIBRE SEPARATOR

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ABSTRACT

A palm nut and fibre separator was designed, fabricated and tested. The basic features of the separator are feeding chute, pulverizing unit, separating unit, discharge outlets and the prime mover. The machine was tested at three different machine angle of tilt (10^0, 20^0 and 30^0), two different levels of moisture content termed (dry and wet) and three levels of fibre discharge openings (5, 10 and 15mm). Test results showed that the machine gave its best work performance with dry mixture at 10mm fibre discharge opening and 20^0 machine angle of tilt. The throughput capacity, separating efficiency and quality performance efficiency were 201.4kg/hr, 96.3% and 81.2% respectively. The cost of producing one unit of the palm nut and fibre separator as at the time of fabrication was estimated to be twenty thousand, four hundred and sixty naira (₦20,460) not including the cost of electric motor, and the power required for operating the machine was 2.25kW.

Keywords: palm nut, fibre separator, performance evaluation, efficiency, throughput-capacity.

INTRODUCTION

Oil palm (Elaeis guineensis Jacq.) is an indigenous plant to West Africa. It is the highest oil yielding crop per hectare in the plant kingdom (Kurki *et al.,* 2008). The palm tree bears its fruits in bunches which vary in weight from 10 to 40kg. The individual fruit ranging from 60 to 70g, is made up of an outer skin (exocarp), a pulp (mesocarp) containing the palm oil in a fibrous matrix, a central nut consisting of a shell (endocarp) and the kernel which it self contain an oil, quite different to palm oil, resembling coconut oil (FAO, 2004).

In view of the high utility of kernel and its products, the demand for it in most Nigeria markets is increasing daily. Palm kernel from the cracked palm nuts are crushed in the palm kernel mill to get the palm kernel oil that is used for soap making, glycerine, margarine, candle, pomade, oil paint, polish and medicine. The kernel cake serve as ingredient for livestock feeds and it is widely used in livestock industries while the fibres are used in the boiler as fuel (Adebayo, 2004; Emeka and Olomu, 2007).

Over the years, extracting and expression of oil from oil seeds involve a wide range of traditional, chemical and mechanical processes (Tang and Teoh, 1985; Olayanju *et al*., 2004; Kurki *et al*., 2008). However, survey results showed that 80 percent of Nigerian's oil palm resource exist in small holder plantations and wild groove (Badmus, 2002), thus the nation's oil palm industry is still subsistent with few large estate plantations that make large mills and imported mills relatively expensive and unaffordable by most farmers, thereby making the traditional and small-scale mill to predominate. Sanni and Adegbenjo (2002) also reported that while the palm oil production stages in the processing line had undergone a great deal of mechanical development, the palm kernel oil production is still less mechanized and this production process actually begin with the separation of the palm nuts from the fibre. Figure-1 shows the various steps in processing of palm fruits into palm oil and palm kernel oil.

Traditionally, the separation of nuts from fibre is by using a woven basket to bring out the mixture of nuts and fibre from the bottom of the processing pit, and rocking the basket back and forth to facilitate the movement of the fibre (with lower density) to the top of the nuts (with higher density) after which the fibre are packed out of the basket, thus separating the nuts from the fibre (Sanni and Adegbenjo, 2002). Apart from the drudgery, time wasting and health hazards associated with this process, addition winnowing may be necessary as sizeable quantity of fibre is still retained in the nuts.

Though some semi-automated small-scale mills sometimes make use of the mechanical digester as alternative, it is still essential to separate the palm nuts from the fibre due to some set back with the method. Therefore, this research work is aimed at solving the associated problems and difficulties inherent in the separation of palm nuts from fibre by designing and fabricating a machine with locally available material, that is better efficient, easy to operate, easy to maintain and affordable to both small and medium-scale palm oil processor.

MATERIALS AND METHODS

Machine description and operation

The palm nut and fibre separator consists of five basic units viz: the feeding unit, pulverizing unit, the separating unit, the discharge outlets and the prime mover. The clogged mixture of palm nuts and fibre obtained from the palm fruit expeller are fed through the hopper into the machine. The hopper is made from 16-gauge mild steel sheet formed into a pyramidal frustum with a top opening of 300mm x 300mm, a bottom opening of 190mm x 190mm and a height of 250mm with sides inclined at 75^0 to help the free flow of the nut/fibre mixture into the pulverizing unit.

The pulverizing unit is where the clogged mixture is been broken into smaller particle sizes to release the entangled nuts within the fibre. The unit consists of a shaft, 900mm length made up of 25mm mild steel rod and a 75mm diameter pipe. Attached to the shaft are beaters made of 12mm diameter mild steel rods which are

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arranged alternately at spacing of 100mm from one another so as to produce the necessary effect of breaking the clogged mixture, thereby detaching the nuts from the fibre.

Underneath the pulverizing unit is the separating unit which can also be referred to as the nibbling unit. It is where the actual separation of the palm nuts and fibre takes place. The unit also consists of a shaft, 900mm length made up of 25mm mild steel rod and 75mm diameter pipe, but with flat bars of 2mm thickness and 900mm length attached parallel to the shaft at 40mm spacing. The shaft is strategically positioned to give an adjustable fibre discharge opening (also referred to as fibre discharge outlet). The fibre is discharged through the opening while the palm nuts are conveyed to the other end of the machine to be discharged at the nut discharge outlet.

The machine is powered by a 2.25kw (3hp) electric motor with the aid of belt and pulley arrangement which has 175mm diameter driven pulley and 75mm diameter driver pulley. Figure-2 shows a pictorial view of the machine.

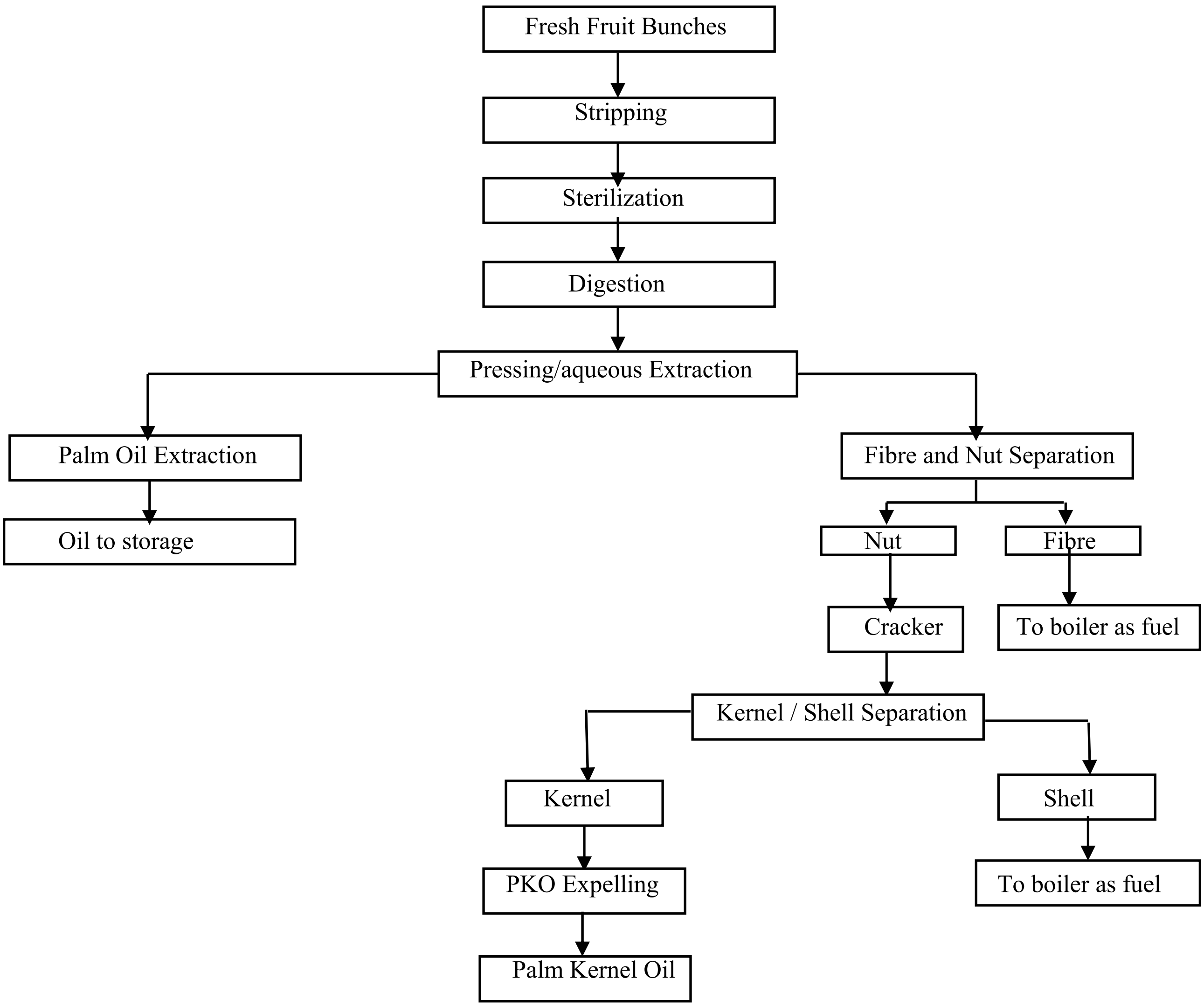

Figure-1. Steps involved in processing palm fruits into palm oil and palm kernel oil (FAO, 2004).

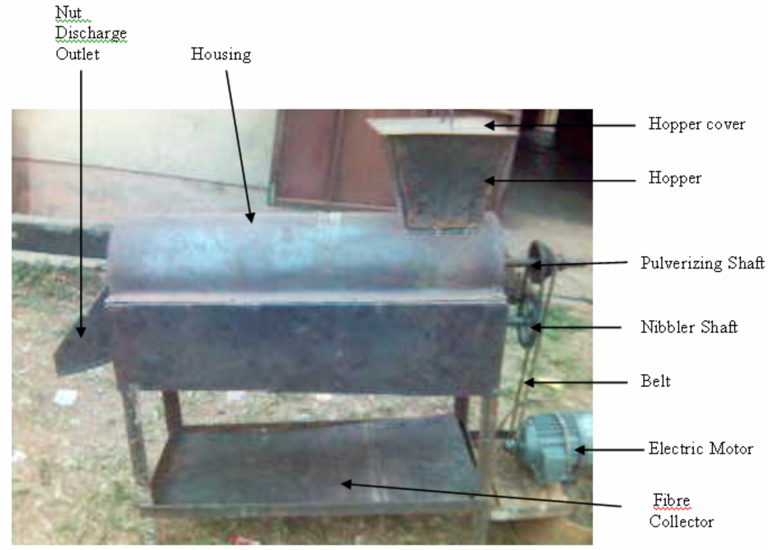

Figure-2. Picture of the palm nut and fibre separator.

Design considerations

Some of the factors which were taken into account while designing the palm nut and fibre separator are as described:

(i) Crop factors such as size, shape, surface texture, moisture content were considered in the design of the machine for the purpose of separating the palm nuts from the fibre.
(ii) Machine factors such as rigidity, deflection, wear; corrosion, vibration and stability were considered in the selection of appropriate material and in sizing and shaping of the various machine components for reliability.
(iii) Machine was constructed of locally available material to enhance the possibility of replacing damaged parts with less expensive but equivalently satisfactory parts that is readily available.
(iv) The overall cost was considered through critical value analysis in the phases of design and production which at the end would make it affordable by farmers and other intending users.
(v) Provision of different chutes for the discharge of nuts and fibres so as to have complete separation.

Design analysis

The major designs were on the feeding chute, power requirement, beater and nibbler shafts, pulley and belt drive.

Feeding chute

The palm nut and fibre separator is expected to have a targeted throughput capacity of 250kg/hr. Therefore, a hopper that is a pyramidal frustum was selected with top opening of 300mm x 300mm, bottom opening of 190mm x 190mm and a side length of 250mm that is incline at 75^0 (angle greater than the dynamic angle of repose of material on mild steel sheet) to ensure the easy flow of mixture into the pulverizing unit.

Power requirement

The power requirement of the machine was determined with the expression by Kurmi and Gupta (2005)

$$P = 2 \pi n T/60 \qquad (1)$$

Where P = power (watt), n = shaft speed (rpm) and T = torque required to turn the shaft at the circumference of the driven pulley (Nm). Power required to drive the shaft = 1.91kw
Assuming, 10% power loss due to friction, total power required = 2.10kw
Therefore, an electric motor of 2.25kw (3hp) was selected.

Pulley and belt drive

The mechanisms and systems in the machine are driven through the v-belt and pulley arrangement with the nibbler shaft taken its drive directly from 2.25kW electric motor of 1420rpm speed.
With the power rating, a belt of type A cross-sectional symbol was selected (PSG Design Data, 1982).
Thus, recommended minimum pulley pitch diameter, d = 75mm
Belt speed, is given by

$$S = \pi dn \qquad (2)$$

Where d=diameter drive pulley, (m) and n = speed of the driver pulley (rpm).
Calculated belt speed, S = 4.8m/s
Speed of nibbler shaft, n_2 = 600rpm; Diameter of nibbler shaft, D = 175mm

The pulverizer shaft took its drive from nibbler shaft, thus the pulley size was determined using the expression.

$$D/d_2 = (n_2/n_1)\,\eta \qquad (3)$$

Where D = diameter of the driver (nibbler) pulley, d_2 = diameter of driven (pulverizer) pulley, n_1 = speed of driver

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pulley, n_2 = speed of driven pulley and η = assumed efficiency of the drive = 0.98.
Calculated pulley diameter = 178.6mm
Selected pulley diameter = 180mm.

Shaft Selection

The pulverizer and nibbler shafts were selected using the ASME code equation for solid shaft having little or no axial loading (Hall *et al*., 1980)

$$d^3 = 16/\pi S_S [(K_bM_b)^2 + (K_tM_t)^2]^{1/2} \quad \text{-------------} \quad (4)$$

Where d = shaft diameter (m), M_b = maximum bending moment (Nm), M_t = maximum torsional moment (Nm), K_b = combined shock and fatigue factor applied to bending moment = 1.5; K_t = combine shock and fatigue factor applied to torsional moment = 1.0, S_S = ultimate stress of mild steel without key way = 55MN/m^2.
Calculated pulverizer shaft diameter = 24.80mm
Calculated nibbler shaft diameter = 24.67mm
Therefore, shaft of 25mm was selected for both.

Performance test procedure

The machine was set up and operated with no load for five minutes to ensure that the various components were functioning properly. Thereafter, appreciable quantity of nut/fibre mixture that was acquired from a medium-scale palm oil mill at Idasen, Owo was prepared in batches of 3kg sample for the performance test.

The separator was evaluated at three different machine angle of tilt (10^0, 20^0 and 30^0), two levels of moisture content (dry and wet) and three different fibre discharge opening (5, 10 and 15mm). Table-1 shows the experimental plan for evaluating the separator.

Table-1. Experimental plan for evaluation of the palm nut and fibre separator.

#	Variables	Levels
1	Machine angle of tilt (^{0})	10, 20, 30
2	Fibre discharge opening (mm)	5, 10, 15
3	Moisture Content	dry, wet
4	Feed rate (kg/hr)	300

The separating efficiency, quality performance efficiency and throughput capacity were evaluated at each combination of variables. In each of the test, 3kg sample was randomly fed through the hopper into the machine and the time taken for the nut fibre mixture to be completely separated was taken using the stop watch. After each operation, the separated and unseparated nuts and fibre from the two outlets were carefully sorted out and weighed. This procedure was replicated three times for each variation and the average taken.

These terms and nomenclature were adopted in the analysis of the performance.
Throughput capacity, C_t is express as

$$C_t = (W_n + W_f)/T_a \quad \text{--} \quad (5)$$

Where W_n = weight of nuts collected after separation (kg), W_f = weight of fibre collected after separation (kg) and T_a = average separation time (hr).

Separation Efficiency, E_s

$$E_s = \left\{(W_n + W_f)/W_m\ 100\right\} \quad \text{--------------------------------} \quad (6)$$

Where W_m = weight of nut/fibre mixture sample fed into the machine (kg)

$$E_Q = \left\{W_{nn}/\ (W_{nn} + W_{nf})\right\}\left\{W_{ff}\ /\ (W_{ff} + W_{fn})\right\} \quad \text{-------------} \quad (7)$$

Quality performance efficiency, E_Q

Where W_{nn} = weight of separated nuts at the nut discharge outlet (kg), W_{nf} = weight of nuts at the fibre discharge outlet (kg), W_{ff} = weight of separated fibre at fibre discharge outlet (kg) and W_{fn} = weight of fibre at nut discharge outlet (kg)

RESULTS AND DISCUSSIONS

The performance of the separator was evaluated at the various machine angle of tilt, levels of moisture content and different fibre discharge openings. The throughput capacity, separating efficiency and quality performance efficiency were calculated with equation 5, 6 and 7, respectively. Table-2 gives the results of the performance test.

Throughput capacity

The throughput capacity ranged from 170.1kg/hr to 250.6kg/hr for the machine tilt angle of 10^0 to 30^0 and fibre discharge opening of 5mm to 15mm when tested with dry mixture while it ranged from 125.8kg/hr to 216.1kg/hr when tested with wet mixture under the same variations. For the different fibre discharge opening and machine angle of tilts, the throughput capacity increases. This is due to the easy of discharge of the material from the separating unit, thus reducing the time of processing with appreciable effect on separation efficiency. Table-2 shows that the machine throughput capacity of 201.4kg/hr and 177.7kg/hr corresponded with best separation result at 10mm fibre discharge opening and 20^0 machine angle of tilt for dry and wet mixture, respectively.

Separation efficiency

The separation efficiency of the machine ranged from 65.6% to 96.3% for the tilt angle of 10^0 to 30^0 and fibre discharge opening of 5mm to 15mm when tested with dry mixture while the separation efficiency ranged from 63.6% to 90.1% when tested with wet mixture under same variations. The separating efficiency is significantly high at 20^0 machine angle of tilt and 10mm fibre discharge opening for dry mixture. Therefore, it is recommended that the nut/fibre mixture be dried before separation as the results closely follow that reported by Sanni *et al* (2009).

Quality performance efficiency

The quality performance efficiency is the product of the separating efficiency for nut and separating efficiency for fibre. Table-2 shows that the quality performance efficiency was influenced significantly by the machine tilt, fibre discharge opening and moisture content. The performance quality was least at 10^0 machine angle of tilt and 5mm fibre discharge opening when tested with wet mixture. This is because greater percentage of the fibre went with the nuts to be discharge at the nut discharge outlet, as some of the fibres were trapped in the fibre discharge opening thus causing a partial blockage of the opening. Also, the quality performance at 30^0 machine tilt angle and 15mm fibre discharge opening was low despite very high throughout capacity as there were appreciable quantity of nut in the fibre discharge outlet and vice-versa. Generally, the quality performance efficiency is optimum at 20^0 machine angle of tilt and 10mm fibre discharge opening for both dry and wet mixture.

Table-2. Performance of the separator at different angle of tilt, moisture content and fibre discharge opening.

A. Machine angle of tilt 10^0						
	Dry			**Wet**		
Fibre discharge opening (mm)	5	10	15	5	10	15
Separating efficiency (%)	65.6	75.2	70.4	64.2	70.1	63.6
Quality performance efficiency (%)	44.4	56.2	50.1	41.4	50.9	42.6
Throughput capacity (kg/hr)	170.1	190.4	205.1	125.8	150.1	171.2
B. Machine angle of tilt 20^0						
	Dry			**Wet**		
Fibre discharge opening (mm)	5	10	15	5	10	15
Separating efficiency (%)	79.1	96.3	86.5	65.5	90.1	80.2
Quality performance efficiency (%)	56.4	81.2	68.4	46.1	70.9	48.3
Throughput capacity (kg/hr)	184.1	201.4	221.1	165.1	177.7	188.3
C. Machine angle of tilt 30^0						
	Dry			**Wet**		
Fibre discharge opening (mm)	5	10	15	5	10	15
Separating efficiency (%)	76.8	86.1	80.4	70.1	78.2	74.5
Quality performance efficiency (%)	50.2	67.9	56.0	50.0	55.1	51.2
Throughput capacity (kg/hr)	206.3	238.2	250.6	187.4	201.5	216.4

CONCLUSIONS

A palm nut and fibre separator was designed, fabricated and tested at Rufus Giwa Polytechnic, Owo. The performance of the separator was quite appreciable in many of the test cases. However, the machine optimum performance was during the separation of dry mixture which gave a throughput capacity of 201.4kg/hr and separating efficiency of 96.3%. With this performance, the machine will culminate the associated problems and difficulties in the traditional method of separation. It is, therefore, recommended for both small and medium scale processors.

REFERENCES

Adebayo A. A. 2004. Development and Performance Evaluation of a motorized palm-nut cracking machine. Proceedings of the Annual Conference of the Nigerian Institution of Agricultural Engineers. 26: 326-330.

Badmus G. A. 2002. An overview of oil palm processing in Nigeria. Proceedings of Agricultural Engineering in Nigeria: 30yrs of University of Ibadan Experience. pp. 76-87.

Emeka V. E. and Olomu J. M. 2007. Nutritional evaluation of palm kernel meal types 1. Proximate composition and metabolizable energy values. African Journal of Biotechnology. 6(21): 2484-2486.

FAO. 2004. Small scale palm oil processing in Africa. FAO Agricultural Service Bulletin148.

Hall A. S., Holowenko A. R. and Laughlin H.G. 1980. Theory and problems of machine design S. I. Metric Edition. McGraw-Hill Book Company, New York. p. 115.

Kurki A., Bachmann J., Hill H., Ruffin L. and Lyons B. 2008. Oil seed processing for small-scale producers. A publication of ATTRA. National Sustainable Agricultural Information Service. www.attra.ncat.org.

Kurmi R. S and Gupta J. K. 2005. A Textbook of Machine Design. 15th Edition. Schand and Company Ltd. New Delhi, India.

Olayanju T. M. A., Akinoso R. and Oyeku O. M. 2004. An investigation into the machine parameters of some vegetable oil expeller. Proceedings of the Annual Conference of the Nigerian Institution of Agricultural Engineers. 26: 387-390.

PSG Design Data. 1982. Compiled by Faculty of Mechanical Engineering, PSG College of Technology, Combatoire, India.

Sanni L.A and Adegbenjo A. O. 2002. Properties of palm nuts and fibre residue that influence mechanical separation after palm oil extraction. Proceedings of the Regional Workshop on Promotion of Appropriate Agro-Processing Technologies in West Africa, Ile-Ife, Nigeria. Post Harvest Technology Research Group. pp. 186-196.

Sanni L.A., Adegbenjo A. O. and Faborode M. O. 1999. Design and construction of an inclined draper-belt for separation of palm nuts from fibre. Proceedings of the 3rd International Conference of WASAE and 9th National Conference of NIAE. 31: 67-74.

Tang T. S. and Teoh P. K. 1985. Palm kernel oil extraction. The Malaysian experience. JAOCS. 62(2): 254-258.