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DEVELOPMENT OF A DUAL POWERED PALM FRUIT STRIPPER

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ABSTRACT

A palm fruit stripper that is dual powered was designed, fabricated and tested. When manually powered, the machine has a throughput capacity of 0.612 tonne/hr, stripping efficiency of 68.9% and quality performance efficiency of 47.4% at a sterilization time of 90 minutes. When powered by an electric-motor and tested at three beater speed (250, 350 and 450rpm) with quartered bunches sterilized at 30, 60 and 90 minutes, the machine gave its best work performance at 450rpm and sterilization time of 90 minutes. The maximum throughput capacity, stripping and quality performance efficiencies were 2.14 tons/hr, 96.1% and 81.9%, respectively. The cost of producing one unit of the palm fruit stripper as at the time of fabrication was estimated to be eighteen thousand, three hundred and fifty naira (₦18,350) not including the cost of electric motor and the power required when operated with electric motor was 2.25kw.

Keywords: palm fruit stripper, performance evaluation, bunch stripping, throughput capacity, machine efficiency, palm oil.

INTRODUCTION

The oil palm (*Elaeis guineensis*) is a popular tree crop in West Africa that is described as the prince of the plant kingdom because virtually every part of it has economic value. It plays an important role in the agricultural and economic sectors of those countries where it is found. Report revealed that 338 billion pounds was generated from the cultivation of oil palm thus amounting to about twice the level of production of any other fruit crop, making oil palm by far the world's number one fruit crop (FAO, 2004). The palm oil and palm kernel oil have a wide range of applications, about 80 percent of the palm oil produced finds it way into food products while the rest is feedstock for a number of non-food application (Salmiah, 2000). The by products of oil palm fruit processing such as empty bunches and fibres can further be process as raw materials for potash fertilizer, fibre, pulps and paper manufacture (Mijinyawa and Ogunbanjo, 2003).

Though the technology of palm oil production has advanced in recent years with new technological innovation to produce palm oil and palm kernel oil of superior quality (Stock, 1961), survey results showed that 80 percent of Nigerians oil palm resource exist in small holder plantations and wild groove (Badmus, 2002), and thus the nation's oil palm industry is still subsistent with very few large estate plantations that make large mills and imported mills relatively expensive and unaffordable by most farmers, thereby making the traditional method to predominate.

Traditionally, the harvested palm fruit bunches is heaped and allowed to ferment to facilitate easy stripping of the fruits. The picked fruits are then collected and digested into a mash, after which it is mixed with water and agitated in a pit to separate the crude oil from the mixture. After adequate mixing, the oil that floats at the tip is scooped off for clarification. Apart from the drudgery, time wasting and high labour requirement in this method, it gives poor quality oil as the period of fermentation increases the free fatty acid (FFA) content of the oil. According to Badmus (1991), processing the fruit without delay or fermentation yielded the highest oil extraction of 87 percent and best quality oil with free fatty acid (FFA) of 2.31 percent. Hence, it is important that fresh fruit bunches be processed as soon as possible so as to prevent a rapid rise in free fatty acid which normally affect the quality of crude palm oil.

Therefore, this research work is aimed at solving the associated problems and difficulties facing the farmers in the business of palm oil processing in Nigeria by designing and fabricating a machine with locally available material that is low-cost, higher through put, better efficient, easy to operate, easy to maintain and affordable to both small and medium scale palm oil processors.

MATERIALS AND METHODS

Machine description and operation

The palm fruit stripper consists of four basic units viz: The feeding unit, the stripping unit, the drive mechanism and the discharge outlets. The quartered palm fruit bunches is fed through the hopper into the stripping unit. The hopper is made from 16-gauge sheet metal formed into a trapezoidal shape designed to handle a targeted machine capacity of 2.0 tons fruit bunch per hour. It has a vertical height of 330mm with sides inclined at 50^0 to the frame work to help slide the quartered bunches into the stripping unit.

The stripping unit is where the fruits are being detached from the quartered bunches. The unit consists of a shaft made up of 25mm mild steel rod, a housing made from 16-gauge sheet metal rigidly mounted on the frame to withstand the load it has to bear, and mild steel rods of 10mm diameter laid horizontally and inclined at 60^0 in spacing of 50mm to the housing to ensure throwing up of the bunches without becoming jammed half-way. The shaft is 1200mm long and attached with beaters, each of 12mm diameter and 100mm long helically spaced at 50mm to produce the necessary impact that detach the fruits as well as convey the stripped bunches from the point of entry to the point of discharge.

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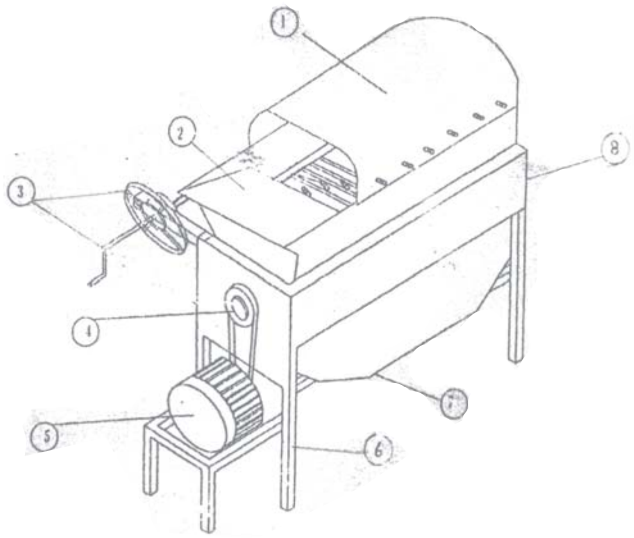
The machine is powered manually through a crank mechanism and also powered electrically with the aid of belt and pulley arrangement which has 230mm diameter driven pulley and 75mm diameter driver pulley connected to a single phase 2.25kw electric motor. As the shaft rotates, the impact of the beaters on the bunches detach the fruits which are collected at the fruit discharge outlet located beneath the stripping unit while the stripped bunches are conveyed to be discharged at the stripped bunch discharge outlet. Figure-1 shows the isometric view of the dual powered palm fruit stripper.



#	Legend	#	Legend
1	Housing	5	Electric Motor
2	Feeding Chute	6	Frame
3	Crank Mechanism	7	Fruit Outlet
4	Driven Pulley	8	Stripped Bunch Outlet

Figure-1. Isometric view of the palm fruit stripper.

Design considerations

Some of the factors which were taken into account while designing the palm fruit stripper are as described:

Reliability and performance of the various components

Factors such as rigidity, deflection, wear, corrosion, vibration and stability were considered in the selection of appropriate material, sizing and shaping of the various machine components. Also, in order to take into account a number of uncertainties such as variation in material properties, effect of environment in which the machine is expected to operate, and the overall concern for human safety, provisions were made through the use of factor of safety stipulated by standard and experience.

Availability of materials

The machine was constructed of locally available materials so as to enhance the possibility of replacing damaged parts with less expensive but equivalently satisfactory parts that are locally available.

Simplicity

The ease of design and fabrication of machine for productivity were considered, bearing in mind the need of dismantling to carry out routine cleaning and maintenance of the machine when necessary so as to maintain higher level of performance. And also for the possibility of conveying the machine from one point of use to the other whenever the need arises.

Effectiveness

Meeting the farmers general requirements with minimum loss of oil that may arise from oil being absorbed and carried off by the stalks of the stripped bunches or loss due to unstripped fruits still attached to the bunches. And also the need to have a fruit discharge outlet that is different from the stripped bunch discharge outlet for optimum separation.

Cost

The reduction of cost was taken into account through critical value analysis on the phases of design, material selection, production and maintenance of the machine which at the end make it affordable by farmers and other intending users.

Design analysis

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

Feeding chute

The stripper is expected to have a threshing capacity of 2.0 tonnes of fruit bunches per hour. A hopper that is trapezoidal in shape was selected with base length of 1200mm, base width of 350mm and a side length of 350mm that is inclined at angle 50^0 (angle greater than the dynamic angle of repose for fruit bunches on mild steel sheet) to ensure easy loading of the bunches into the stripping unit.

Power requirement

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

$$P = 2\pi nT / 60 \quad (1)$$

Where

P = power required (watt), n = beater shaft speed (rpm) and T = torque required to turn the beater shaft at the circumference of the driven pulley (Nm).
Power required to drive the shaft = 1.85kW.
Loss of power due to friction was assumed to be 10 %, thus total power = 2.04kW

Therefore, an electric motor of 3 horsepower (2.25kW) was selected for the machine.

Pulley and belt drive

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All mechanisms and systems in the machine are to be driven through v-belts and pulley. The drive for the beater shaft is to be taken from 3 hours power electric motor.

Hence, a belt of type A cross-sectional symbol was selected (PSG Design Data, 1982). Recommended minimum pulley pitch diameter, d = 75mm.
Belt speed, S is given by

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

Where d = diameter of driver pulley, (m) and n = speed of the driver pulley (rpm).
The calculated belt speed = $5.6ms^{-1}$

The diameters of the three different pulleys that were used were determined at 250rpm, 350rpm and 450rpm using the relation.

$\frac{D}{d} = \frac{n1}{n2}\eta$ ---
(3)

Where D = diameter of the driven pulley, d = diameter of the driver pulley, n_1 = speed of the driver pulley, n_2 = speed of the driven pulley and η = assumed efficiency of the drive = 0.98.

Driven pulley diameters of 230mm, 300mm and 400mm were selected base on the calculated values.

Shaft diameter

The shaft diameter was determined using the ASME code equation for solid shaft having little or no axial loading (Hall *et al.*, 1980)

$d^3 = 16 / \pi Ss\sqrt{(K_bM_b)^2 + (K_tM_t)^2}$ --------------------- (4)

Where d = shaft diameter (m), M_b = maximum bending moment (Nm), Mt = maximum torsional moment (Nm), K_b = combined shock and fatigue factor applied to bending moment = 1.5, K_t = combined shock and fatigue factor applied to torsional moment = 1.5, Ss = ultimate stress of mild steel with keyway = $40MN/m^2$.
The diameter of shaft was calculated as 24.61mm
Therefore, a diameter of 25mm was selected.

Performance test procedure

In order to evaluate the performance of the machine, an experiment was designed such that the stripper was tested under two power sources (manual and motorized). For manual operation, the operating speed of the beater shaft was determined by the rotation of the crank assembly while three different speeds of 250, 350rpm and 450rpm were used in the motorized test. For the required speeds the beater shaft pulley that gave the desired speed was used.

In all the test, 5kg sample of the quartered bunches sterilized under time variation of 30, 60, and 90 minutes were randomly fed through the hopper. The time taken to thresh each sample was measured using a stop watch. After each operation, the stripped fruits, unstripped fruits and stripped bunches from the outlets were carefully sorted out and weighted. This procedure was repeated four times for each variation and the average taken.

These terms and nomenclature were adopted in the analysis of the performance:

Throughout capacity, C_t is express as:

$C_t = W_b / T_a$, kg/hr -------------------------------------- (5)

Where W_b = weight of quartered bunches that was stripped (kg) and T_a = average time of stripping (hr).

Stripping efficiency, Es

$E_s = (W_f / W_t)\ 100$ ------------------------------------- (6)

Where W_f = total weight of stripped fruits and W_t = total weight of fruits in the quartered bunches that was stripped.

Quality Performance Efficiency, E_Q

$E_Q = \{(W_{fs} / (W_{fs} + W_{fb})\}\ \{W_{bs} / (W_{bs} + W_{bf})\}$ -------------- (7)

Where W_{fs} = weight of stripped fruits at the fruit discharge outlet, W_{fb} = weight of fruits at the bunch discharge outlet, W_{bs} = weight of stripped bunch at the bunch discharge outlet and W_{bf} = weight of stripped bunch at the fruit discharge outlet.

RESULTS AND DISCUSSIONS

The performance test results are presented in Tables 1 and 2. The throughput capacity, stripping and quality performance efficiencies were calculated with equations 5, 6 and 7, respectively. For both manual and motorized operation, the stripping time generally decreases with increase time of sterilization. This is attributed to the fact that the more the sterilization time, the more the weakening of bond between the fruits and the stalk and thus making detaching the fruits from the bunches relatively easier. This explains the increase in throughput capacity as sterilization time increases. Likewise, the stripping and quality performance efficiencies increase with increase sterilization time as increase number of stripped fruits is recovered from the fruit outlet. Table-2 further shows that as beater shaft speed increases, the stripping and quality performance efficiencies also increase. This is because the impact force applied to the bunch at higher speed is greater than that at lower speed.

In all the tests carried out in the machine when motorized, the throughput capacity, stripping efficiency and quality performance efficiency were significantly high when compared with those carried out when manually operated. At 90 minutes sterilization time and 450rpm beater shaft speed, the throughput capacity, stripping and quality performance efficiencies are 2.14 tons/hr, 96.1% and 81.9%, respectively, while manually operated at 90 minutes sterilization time gave throughout capacity, stripping and quality performance efficiencies of 0.612 tonne/hr, 68.9% and 47.4%, respectively. This is in line with the mechanical advantage derivable from the level of machine.

Table-1. Performance of the stripper when manually operated at different time of steaming.

Sterilization time (min)	**30**	**60**	**90**
Weight of quartered bunches for stripping (kg)	5.0	5.0	5.0
Weight of fruit stripped at fruit outlet (kg)	1.27	1.31	1.36
Weight of stripped bunches at bunch outlet (kg)	0.75	0.71	0.64
Weight of stripped bunches at fruit outlet (kg)	1.96	2.01	2.09
Average stripping time (min)	**0.60**	**0.52**	**0.48**
Output capacity (tons/hr)	0.500	0.578	0.612
Stripping efficiency (%)	60.1	64.9	68.9
Quality performance efficiency (%)	39.5	43.7	42.4

Table-2. Performance of the stripper when powered with electric motor at different beater shaft speed and time of steaming.

A. Beater shaft speed: 250rpm			
Weight of quartered bunches for stripping (kg)	5.0	5.0	5.0
Sterilization time (min)	30	60	90
Average stripping time (min)	0.32	0.30	0.27
Throughput capacity (tons/hr)	0.938	1.000	1.111
Stripping efficiency (%)	6.31	64.9	70.7
Quality performance efficiency	42.6	44.2	48.2
B. Beater shaft speed: 350rpm			
Weight of quartered bunches for stripping (kg)	5.0	5.0	5.0
Sterilization time (min)	30	60	90
Average stripping tons (min)	0.25	0.22	0.18
Throughput capacity (tons/hr)	1.200	1.364	1.667
Stripping efficiency (%)	72.7	73.7	82.5
Quality performance efficiency	51.5	54.7	66.0
C. Beater shaft speed: 450rpm			
Weight of quartered bunches for stripping (kg)	5.0	5.0	5.0
Sterilization time (mm)	30	60	90
Average stripping time (min)	0.16	0.15	0.14
Throughput capacity (tons/hr)	1.875	2.000	2.140
Stripping efficiency (%)	84.3	89.7	96.1
Quality performance efficiency	68.4	74.3	81.9

However, while it is appreciable to have a much higher throughput with the motorized operation, the increased stripping and quality performance efficiencies are evidences that a speed of 450 rpm is optimum for the stripper at 90 minutes sterilization time. Generally, the result closely follows those reported by Stork (1960) that the throughput capacity, stripping and quality performance efficiencies increase with increase on sterilization time and beater shaft speeds.

CONCLUSIONS

A palm fruit stripper that can be manually and electric-motor operated was designed and constructed with locally available materials. Based on the performance test results, the throughput capacity, stripping and quality performance efficiencies increase with sterilization time and beater shaft speed. Using the electric motor for operating the palm fruit stripper is preferred to manually powered operation. It gave the best work performance at 450rpm with throughput capacity of 2.14 tons/hr, stripping efficiency of 96.1% and quality performance efficiency of 81.9%. However, both were of greater performance than the traditional methods. Therefore, this simple machine can help solve the associated problems and difficulties of palm fruit bunch stripping, especially for small and medium-scale farmers.

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