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#### Development of a Low Cost Motorized Oil Palm Fruit Bunch Stripper

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#### Abstract

Oil palm is an economic plant with great importance because of its revenue generation capacity. The major bottleneck in the oil palm fruit processing in Nigeria especially in the small scale oil palm processing industries is the stripping of oil palm fruits from their bunches and most of palm fruit processors are low income earners who might not be able to afford the existing palm fruit bunch stripper due to their high cost. A low cost motorized stripper was developed in order to overcome this challenge. The components of the stripper which consist of a power source, the stripping unit housing, the speed gear and shaft, the stripping unit, fruit and bunch outlets and the supporting frame were fabricated using locally sourced materials. The stripper was tested to evaluate its performance efficiency. Freshly harvested palm fruit bunches at different fermentation time of 24, 36, 48, 60 and 72 hours was used. High fruit stripping efficiency of 98.8% was recorded at fermentation time of 72 hours and lowest of 72.84% at fermentation time of 24 hours. It has clean fruit recovery efficiency of 98.57% at 60 hours fermentation and lowest average value of 93.83% at 24 hours fermentation. The highest average value of output capacity 358.77 kg/h at 72 hours and lowest of 202.29 kg/h at 24 hours fermentation time. These results showed that the stripper will be able to handle up to two tons of oil palm fruit bunches in a day at 72 hours fermentation; thus, making it affordable for the small and medium scale oil palm fruit processing industries in Nigeria at a low cost of purchase and maintenance.

Keywords: Development, Fabrication, Oil Palm Fruit, Stripping Efficiency, Performance Test

#### 1. INTRODUCTION

The fresh fruit bunch (ffb) of oil palm (Plate 1) consists of fruits of oil palm embedded in spikelet attached on a main stalk or bunch. Traditionally, stripping is achieved by cutting the fruit-laden spikelet from the bunch stem with an axe or machete and then separating the fruit from the spikelet by hand after fermentation. It serves has source of livelihood for children and the elderly in the villageas casual labourers performing this activity at the factory site. Most small-scale oil palm processors strip the fruitlets off the bunch before the fruits are steamed, while high-pressure sterilization systems steam the bunch at about 40 psi for about 70 – 90 min to ensure the heat is capable of facilitating the detachment of fruitlets (Sivasothy*et al., 2005*).

In the processing of oil palm fruit in Nigeria, stripping of the fruitlets from the spikelet was done manually by hand picking and to ease the detachment of loose fruitlets from the bunch, the ffb are mostly cut into spikelets as threshing materials using a knife blade, axe or circular saw before hand picking which causes bruisesand injuries to the fingers of the processors. Obiakor (1998). This constitutes a major challenge in the processing of oil palm fruits. Apart from the poor quality of oil produced, the techniques are inefficient, time wasting, arduous and requires high labour (Ojomo*et al.*, 2010).

Strippers are needed to thresh out the fruits from the bunch; this led to the development of different strippers. Many types of stripping machines have been developed over time by researchers and only two types have been found to give satisfactory performance in practice. According to Stork (1960), the two types are the beater arm bunch stripper, mostly used in mills of up to 4 or 5 tons ffb/h throughput, and the rotary drum stripper (thresher) commonly used in mills where greater throughput is to be handled.

Aremu and Alade, (2017) developed a palm fruit bunch chopper and spikelet stripper that comprises of chopping chamber, stripping and separating units as the main components of the stripper and reported the chopping efficiency to be about 98% and stripping efficiency to be about 94.04%. FAO (2011), reported a mechanized system for stripping oil palm fruit bunches

consisting of a rotating drum or fixed drum equipped with rotary beaters which detach the fruit from the bunch, leaving the spikelets on the stem produced by NIFOR.

Suryanto and Bardaie, (1996) had reported that brushing 4-gram ethephon of 20-30% concentration on cut bunch/spikelet stalk would hasten the fruitlet abscission and reduce the stripping force from about 300 N to less than 20 N after storing the ffb for 24hours. Another study also reported by Suryanto and Bardaie, (1996) showed that the application of ethephon would not affect the development of ffb. It was discovered that despite the number of strippers developed, many small – scale processors in Nigeria could not still used them due to high cost of purchasing a palm fruit bunch stripping machine, this makes them to continue the old practice of stripping palm fruits from the bunches (Oshiobugie et al. 2017).

Therefore, it became necessary to develop a low cost oil palm fruitlet strippers that is affordable by small–scale oil palm fruit processors which will be able to remove the fruitlets from bunches during oil palm fruit processing so as to reduce or eradicate the traditional method of stripping fruitlets from bunches that causes injury or bruise hands of processors. The main aim of this study was to develop a simple, low-cost but effective mechanical stripper for detaching oil palm fruits for use by the small and medium scale oil palm fruit processors.



Plate 1. Picture of Fresh Oil Palm Fruit Bunch.

# 2. MATERIALS AND METHODS

#### 2.1. Design considerations

In the design of the low cost oil palm fruit stripper, the following were taken into consideration:-

- i. Availability of construction materials: materials of adequate strength and stability used for the fabrication were sourced locally.
- ii. Cost: low cost materials that gives adequate strength and stability were used for the fabrication.
- iii. Physical and mechanical properties of oil palm fruits: relevant geometric mean diameter of the palm fruit bunches and fruitlets were considered for the design of the fruitlets and the chaff (bunch) outlets.
- iv. Basic considerations were given to the design of the size, speed and capacity of the stripper.

# **2.2.** Construction Materials

- i. Angle iron (25 x 25mm)
- ii. 16mm ø rods
- iii. Mild Steel rod (40mm ø)
- iv. Mild Steel Sheets (1.5mm and 2.5mm)
- v. Mild Steel Pulley
- vi. Flat Bars (2mm), etc.

# 2.3. Description and Principle of Operation the oil palm fruit bunch stripper.

The strippers (Figure 1) uses the principle of impact to remove the fruitlets from the bunch. It consists of a power source, gear system, frame, stripping unit and outlets for both stripped fruitlets and empty fruit bunches. The stripping unit is made of a rotor assembly made of metal paddles that are attached to a shaft 10 mm away from shaft tip. The rotor assembly passes from bottom of the cylinder to its middle along the Centre of the cylinder. Four bunch beaters are inclined at an angle of  $60^{\circ}$  against the inner wall of the cylinder. The stripping unit housing which is cylindrical in shape with a dimension of 580 mm diameter and 465 mm height is vertically erected on a supporting frame.

The bunch outlet is made of rods which are networked to  $20 \text{ mm} \times 20 \text{ mm}$  squared holes to form sieve (mesh) and runs from the rear end of the bottom of the cylinder to the front at an inclined angle of  $60^{\circ}$  for easy rolling of the fruitlets into a collector. The sieve located at the fruit outlet filters the fruit bras (small chaff) from the fruitlets. An outlet on the side of the cylinder is also

provided for the bunch. The rotor assembly is driven by a gear system which is powered by a 5.5 hp water cooled diesel engine. The frame holds the whole system in a strong and rigid position.



Figure 1.Isometric View of a Low Cost Oil Palm Fruit Bunch Stripper.

# 2.4. Design calculations

Some of the design calculation are given as follow:

a. Stripping unit chamber: The stripping unit chamber is cylindrical in shape and the circumference of the circular section of a cylinder,  $(C_{sc})$  was calculated using the formula given by Akande, (2001) as:

$$C_{sc} = \pi D \tag{1}$$

Where, D is diameter of the cylinder (m).

**b.** Stripping unit designed capacity:Since the stripping unit is cylindrical in shape, the capacity (C<sub>n</sub>) of the stripping was calculated to be using the equation given by Akande, (2001):

$$C_{\rm U} = \pi r^2 h \tag{2}$$

Where, r is radius of the stripping unit (m) and h is height of the stripping unit (m).

**c.** Torsional moment: The torsional moment (M<sub>t</sub>) of the gear shaft was obtained from the equation given by Khurmi and Gupta, (2005) as:

$$M_{t} = \frac{9550xKw}{rev/\min}$$
(3)

Where,  $K_w$  is power required by the gear shaft in kW and r/min is the speed of gear in rpm.

**d. Length of belt:** Belt length (L) was determined using Equation given by Khurmi and Gupta, (2005):-

$$L = \frac{\pi}{2} (d_1 + d_2) + 2X + (d_1 + d_2)^{2/4x}$$
(4)

Where,  $d_1$  is diameter of bigger pulley (Driven Pulley) in (m),  $d_2$  is diameter of smaller pulley (Driving Pulley) in (m) and X is shaft to shaft center in (m).

e. Design for the Gear Shaft: The stripper shaft is subjected to combine twisting and bending moments; the shaft is designed based on two simultaneous moments.Bending moment due to overhange,  $M_1$  is 9.9 x10<sup>-3</sup> Nm whilebending moment due to tangential load on the gear  $M_2$  is 1.73 Nm. The resultantbending moment, M, wasgiven as 1.73 Nm according toKhurmi and Gupta (2005):

$$M = \sqrt{(M_1)^2 + (M_2)^2}$$
 (5)

The combined twisting moment and bending moment was used to determine the shaft diameter by using equation given by Khurmi and Gupta, (2005):-

$$T_{e} = (M^{2} + T^{2})^{0.5} = \frac{\pi \times Ss \times d^{3}}{16}$$
(6)

Where,  $T_e$  is equivalent twisting moment in Nm, M is resultant bending moment in Nm, T is torque transmitted by the gear shaft in Nm,  $S_s$  is allowable shear stress with keyway which equals 45N/mm<sup>2</sup> as given by Khurmi and Gupta, (2005) and d is diameter of the shaft in mm.

Therefore, the equivalent twisting moment,  $T_e$  from equation (6) is 119.49 Nm Hence, the diameter of the shaft was calculated to be 0.0238 m using Equation (7) derived from Equation (6).

$$d = \sqrt[3]{\frac{T_e \times 16}{\pi \times Ss}}$$
(7)

For this design a shaft diameter of 24.00 mm greater than the calculated value was selected.

#### **2.5.Performance Test Procedure**

A performance evaluation test was carried out on the developed motorized (Plate 2) oil palm fruit bunch stripper at operating speed of 450 rpm using an electric motor as power source and ripped oil palm fruit bunches as testing materials to ascertain its performance. The procedure was as follows: freshly harvested palm fruit bunches were stored for 24 hours, 36 hours and 48 hours, 60 hours and 72 hours under a closed system to allow for ripping or fermenting of oil palm fruit bunches for easy loosening of fruitlets. A pre–data experiment was conducted to determine the weight and number of fruitlets that are expected to be a known weight of an oil palm fruit bunch. Bunches were weighed out in three replications of a 10 kg and each weighed bunches were fed into the stripper. The various weights of samples such as weight and number of fruitlets at the outlet, time of stripping were taken and recorded during the evaluation. The data obtained were then used to evaluate the performance parameters.



Plate 2. Pictorial View of the Developed Motorized Stripper.

#### 2.6. Performance Evaluation Test Parameters

The performance test parameters for stripping machines given by Suryanto and Bardaie, (1996) were used to evaluate the performance of the stripper:

a. Fruit Stripping Efficiency,  $S_E$  (%),: This determines how easy the stripper is able to remove or strip fruitlets from the bunch and is expressed in equation 8:

$$\boldsymbol{S}_{E} = \frac{\boldsymbol{N}_{S}}{\boldsymbol{N}_{T}} \times 100 \tag{8}$$

And

$$N_T = N_S + N_U \tag{9}$$

Where,  $N_{s}$  is number of stripped fruitlets,  $N_{U}$  is number of unstripped fruitlets and  $N_{T}$  is total number of fruitlets in the bunch.

**b.** Clean Stripped Fruit Recovery Efficiency (%),  $C_R$ : This determines how efficiently the stripper recovers the clean fruit stripped from the machine and is expressed as the percentage by weight of clean stripped fruitlets received at the fruitlet outlet. It is as shown in equation 10.

$$C_{\rm R} = \frac{M_B}{M_B} x 100 \,(\%)$$

Where,  $M_B$  is weight of stripped fruitlets obtained at the fruitlet outlet, (kg) and  $M_D$  is total weight of fruitlets contained in each bunch, (kg).

(10)

(11)

(12)

c. Input Capacity, $I_{C}$ ,(kg/hr): The weight of whole bunch including processing loss, passing through the stripper per unit time and is expressed in equation 11.

$$I_{C} = \frac{M_{A}}{T}$$

Where,  $M_A$  is total weight of bunches fed into the stripper (kg) and T is time taken to stripe the bunch of oil palm fruits, (s).

**d.** Output capacity,O<sub>C</sub>,(kg/hr): This determines the weight of fruitlets received at the outlet per unit time and expressed in equation 12.

$$O_{\rm C} = \frac{M_B}{T}$$

Where,  $M_B$ Where,  $M_B$  is weight of stripped fruitlets obtained at the fruitlet outlet, (kg) and T is time taken to stripe the bunch of oil palm fruits, (s).

# 3. **Results and Discussions**

The results (Table 1) of the performance tests carried out on the stripper using freshly harvested palm fruit bunches showed that the stripper had its highest average value of fruit stripping

efficiency of 98.8% at fermentation time of 72 hours and lowestaverage value of 72.84% at fermentation time of 24 hours. The highest average value for clean fruit recovery efficiency was 98.57% at 60 hours fermentation time and lowest average value of 93.83% at 24 hours fermentation time. The highest average output capacity of 358.77kg/h was obtained at 72 hours fermentation time and lowest average value of 202.29 kg/h at 24 hours fermentation time.

S/N	Fermentation	Stripping	Output	Input Capacity;	CleanFruit
	Time, $F_T(h)$	Eff.; $S_E(\%)$	Capacity; Oc	$I_C((kg/h))$	Recovery Eff.;
			(kg/h)	_	$C_R(\%)$
1	24	72.75	202.97	329.84	90.91
2	24	70.18	201.25	324.75	95.71
3	24	75.58	202.66	418.43	94.87
Average		72.84	202.29	357.67	93.83
4	36	80.38	236.20	372.43	94.21
5	36	83.37	240.69	405.00	98.98
6	36	81.38	246.27	360.41	97.89
Average		81.71	241.05	379.28	97.03
7	48	90.41	293.12	412.68	99.73
8	48	89.80	294.00	386.86	93.03
9	48	89.59	290.69	356.33	96.74
Average		89.93	292.60	385.29	96.73
10	60	96.20	325.69	397.01	97.04
11	60	97.94	331.66	358.13	99.20
12	60	95.56	327.13	362.60	99.48
Average		96.57	328.16	372.58	<b>98.5</b> 7
13	72	98.55	365.76	349.20	96.72
14	72	99.57	359.86	350.36	95.09
15	72	98.28	350.70	351.00	97.00
Average		98.80	358.77	350.19	96.27

Table 1. Summary of Performance Evaluation Test of the Developed Oil Palm Fruit Bunch Stripper.

# 4. Conclusion and Recommendations

A low cost oil palm fruit bunch stripper was design, fabricated and tested. The developed oil palm fruit bunch stripper was fabricated using locally sourced materials of low cost with adequate strength and stability. The total production cost of Fifty-Five Thousand Naira Only (N55,000) was expended.

The results from the evaluation indicated a satisfactory performance of the stripper;the stripper will be able to handle up to two tons of oil palm fruit bunches in an 8 hours per day operation for 72 hours fermentation time, thus, making it suitable for the small and medium scale oil palm fruit processing industries in Nigeria.

It is recommended that further comprehensive performance evaluation be carried out on the stripper to determine the effects of bunch harvesting period, bunch ripeness before harvesting and speed of operation on the performance of the stripper and on the quantity and quality of the palm oil obtained after extraction.

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