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PERFORMANCE EVALUATION OF A PALM FRUIT BUNCH STRIPPER

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ABSTRACT

A palm fruit stripper that was designed and fabricated at the Department of Agricultural Engineering Technology, Rufus Giwa Polytechnic, Owo was evaluated for the stripping of quartered bunches. Studies were conducted on the effect of machine speed (1500rpm, 2000rpm and 2500rpm) and the time of steaming (10min, 20min and 30min) on the machine out-put capacity, efficiency and quality performance efficiency. The performance of the palm fruit stripper was evaluated at different levels of machine and crop variables. Machine speed and time of steaming statistically affected the machine performance at 5% significance level using the Duncan Multiple Range Test (DMRT). The performance was found to be influenced by all studied variables, however, the machine gave the best stripping efficiency of 93.4%, quality performance of 91.2% and output capacity of 74.9kg/hr with the least damaged seed of 0.4% at 2500rpm machine speed and 30mins time of steaming, when compared with other combinations of variables.

Keywords: palm fruit bunch stripper, performance evaluation, efficiency, output capacity, time, steaming.

1. INTRODUCTION

The oil palm, Elaesis guineenes Jacq originated on the tropical rain forest region of West Africa. The main belt runs through the southern latitude of Cameroon, Cote d'Ivoire, Ghana, Liberia, Nigeria, Sierra Leone and Togo into the equatorial regions of the Republic of Congo and Zaire (Hartley, 1988). However, because of its economic importance as a high yielding source of edible and technical oils, the oil palm is now grown as a plantation crop in most countries with high rainfall (minimum 1600mm/yr) in tropical climates within 10^0 of the equator (FAO, 2004).

The palm bears its fruits in bunches varying in weight from 10 to 40kg. the individual fruit ranges from 6 to 20 grammes and are made up of an outer skin (exocarp), a pulp (mesocarp) that contains the palm oil in a shell (endocarp) and the kernel which itself contains palm kernel oil (Stork,1960). Palm oil and palm kernel oil have a wide range of application about 80% of the palm oil produced finds its way into food products while the rest is feed stock for a number of non-food applications (Berger, 1996; Salmiah, 2000). The palm fruits are obvoid in shape and are of three varieties, the dura types have thick mesocarp with a thin mesocarp, the pisifera types are shell-less variety while the hybrid, tenera types have a much thicker mesocarp, and a thinner endocarp (The Tropical Agriculturist, 1998).

As fruits ripen, they change from black (or green) to orange, but have varying degrees of black cheek colour depending on light exposure and cultivar. The fruit bunches are harvested using chisels or hooked knives attached to long poles. Processing of oil palm fruits bunches into palm oil is practiced using various methods which may be grouped into four categories according to their throughput and degree of complexity of the unit operational machinery. These are the traditional methods that can process less than 1 tonne of fresh fruit bunches (FFB) per hour; the small-scale mechanical units handling up to 2 tonnes of FFB per hour; the medium-scale mills handling between 3 to 8 tonnes per hour and the large-scale mills which are able to process more than 10 tonnes per hour (FAO, 2004; Ilechie, 2004; UNIDO, 1974).

Though the technology of palm oil production has advanced in recent years with new technological innovations to produce palm oil and palm kernel of superior quality; survey results revealed that 80% of Nigeria's oil palm resources exist in small holder plantations and wild groove (Badmus,2002) and thus the Nation's oil palm industry is still substitent with few large estate plantations that makes large-scale mills and imported mills relatively expensive and unaffordable by most farmers, thereby making the traditional method of processing to predominate.

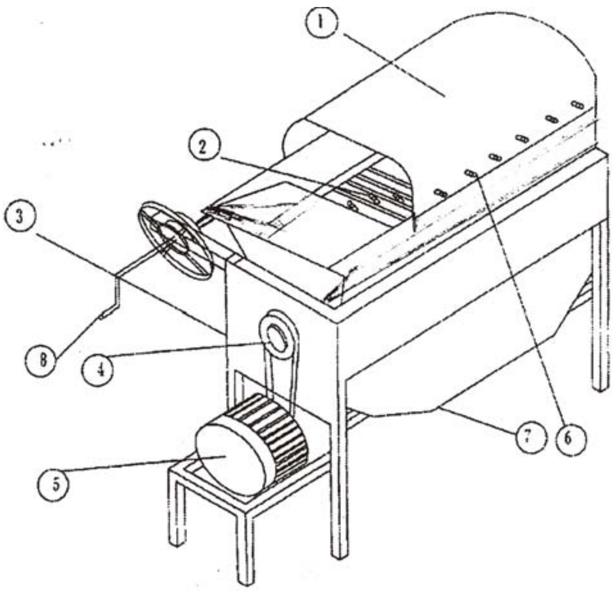
Traditionally, oil is extracted by crude means to give a product of generally poor quality. After harvest, the palm fruit bunches are heaped to ferment for about five days and later beaten with stick to detach the fruitlets from the bunches. The picked fruits are cooked and digested into a mash which is mixed with water and agitated in a pit. After adequate mixing, the oil is separated and floats at the top where it is scooped off for clarification (Sanni and Adegbenjo, 2002). Apart from the poor quality of oil produced, the techniques are inefficient, time wasting, arduous and requires high labour. According to Badmus (1991), processing the fruit without delay or fermentation yielded the highest oil extraction of 87 percent and better quality oil with free fatty acid (FFA) of 2.31 percent and lowest carotenoid content. Hence, it is important fresh fruit bunches (FFB) are processed as soon as possible to prevent a rapid rise in FFA which normally affect the quality of the crude palm oil.

Thus, this paper reports the effect of machine and crop variables on the performance of a designed and locally fabricated palm-fruit stripper for small and medium-scale processing aimed at solving the associated problem and difficulties in the traditional methods.

2. MACHINE DESCRIPTION AND OPERATION

The machine consists of a hopper made from mild steel sheet (SWG16) of vertical height 330mm and slanted height 350mm, base width of 350mm and length 1200mm. The frame is also made from mild steel angle iron bar (1.5x1.5include) 900 mm heights. It has a stripping unit which consisted of the shaft 30mm diameter on which the beaters arms 12mm and 10mm diameters are welded in a spacing of 50mm in an auger like manner in order to ensure that the stripped bunches are pushed towards the bunch discharge outlet while the fruits are collected at the fruit discharge outlet beneath the machine.

Palm fruit bunches are fed into the machine through the hopper to the stripping unit where the shaft with beaters arranged in an auger like form is located. As the shaft rotate through the power transmitted from the electric motor via belt and pulley mechanism, the bunch is thrown up against the housing and at the same time conveyed to the bunch discharge outlet while the fruit is collected beneath the machine. Figure-1 shows the isometric drawing of the palm fruit stripper while Plate-1 shows the machine under operation.



#	Legend	#	Legend
1	Housing	5	Electric motor
2	Beater arm	6	Bolt and nut
3	Frame	7	Fruit outlet
4	Pulley	8	Crank mechanism

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

Plate-1. Picture of the palm fruit stripper.

2.1 Determination of machine capacity

Total weight of fruit stripped = 0.90kg
Total time taken for the operation = 0.083hr
This relationship gives the capacity of the machine:

Machine capacity = $\frac{\text{weight of stripped fruit+empty bunch}}{\text{Time taken (hr)}}$

Machine capacity = $\frac{Wfs+We}{\text{Time (hr)}}$

= $\frac{0.90+0.93}{0.083}$

= 22.0kg/hr

2.2 Determination of the rate of power consumption by the machine

Total power consumed = 1.1kW
Total time of the operation = 0.083hr
Power consumption in kW/hr is given by

Power consumption = $\frac{\text{Power Consumed (kw)}}{\text{Time of operation (hr)}}$

=1.1kW
0.083hr
Power consumption = 13.25kw/hr

2.3 Determination of cost of power/hour

Power required per hour = 13.25kw,
Cost of power/hr in Nigeria = N4
Cost of power per hour = Power required/hr x cost of power per hour
Cost of Power/hr = 13.25 x 4 = N53

2.4 Determination of power required by the machine to strip 1 tonne of oil palm fruit

From the machine capacity determined (22kg/hr), 1 tonne will be stripped by 13.25kw, and therefore to operate the machine for 2hrs, and power required is given as follows:

1 hour, power required = 13.25kw
For 2 hours, power required will be 13.25kw x 2 =26.5kw.

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2.5 Determination of cost of power required for 1 tonne of oil palm fruit

1 unit (1kw/hr), cost N4 in Nigeria

Cost of power required/tonne = power consumed/tonne x cost per/hr.

Power required/tonne = 13.25kw x 4 = 53kw/tone

2.6 Determination of wages of the machine operator

The operator salary was assumed to be N10000 per month. Therefore, the operator will be expected to collect N389.6 per day (26 working days Saturday inclusive) or N48 per hour (8 working hours).

2.7 Performance evaluation

The machine was installed on a level and hard surface. Sixty kilogram of freshly harvested palm fruit was purchased from nearby farm. 5kg of oil palm fruit bunch was prepared for the machine test. Each experiment was carried out in five replicates. The stripper was evaluated at three levels of machine speed and five levels of time of steaming. The stripper was powered by an electric motor of power rating of 2.25kW. The speed of the machine was varied by changing the diameter of the pulley. The diameters of the pulleys used were 230mm 300mm and 400mm corresponding to 1500rpm, 2000rpm and 2500rpm respectively. The feed rate, output capacity, machine efficiency and the quality performance efficiency were evaluated at each combination of variables. The levels of the variables for testing the oil palm fruit stripper are shown in Table-1.

Table-1. Experimental plan for evaluation of oil palm fruit stripper.

Variables	Levels
Machine speed (rpm)	1500, 2000 and 2500
Time of steaming (minutes)	Ranged from 10 to 30

2.8 Determination of feed rate

$$Feed\ rate = \frac{\text{Quantity of bunch feed in}}{\text{Time taken to feed}}$$

$$Fr = \frac{QbF}{TF} \quad (1)$$

2.9 Determination of the output capacity

$$\text{Output capacity} \frac{\text{Weight of palm fruit stripped + weight of empty bunch}}{\text{Time of stripping}}$$

$$Q_c = \frac{WFs + We}{Ts} \quad (2)$$

2.10 Determination of machine efficiency

$$Machine\ efficiency = \frac{\text{Weight of stripped fruits}}{\text{Total weight of fruit in the bunch prepared for stripping}} X\ 100$$

$$M_E = \frac{WFs}{WFT}\ x\ 100\% \quad (3)$$

2.11 Determination of quality performance efficiency

$$\text{Quality Performance efficiency} = \frac{\text{Weight of stripped fruit}}{\text{Weight of empty bunch + weight of fruit unstripped}}$$

$$Q_{PE} = \frac{WFs}{WEb + WFu} X\ 100\% \quad (4)$$

2.12 Determination of percentage of damage fruits

$$Percentage\ of\ damaged\ fruits = \frac{\text{Feed rate - output capacity}}{\text{Total weight of fruits in the bunch prepared for stripping}}$$

$$P_{DF} = \frac{Fr - Qc}{WFT}\ X\ 100\% \quad (5)$$

3. RESULTS AND DISCUSSIONS

The result of the performance analyses are presented in Tables 2, 3, 4 and 5. Table-2 shows that machine speed, time of steaming of bunches and the interaction between machine speed and time of steaming of bunches significantly affected the stripping efficiency, quality performance efficiency, feed rate, output capacity and the percentage of damaged fruits at 5% level of significance.

Table-2. F-ratio for the results of the performance tests.

Source of variation	**Feed rate** (kg/h)	**Output capacity** (kg/h)	**Stripping efficiency** (%)	**Quality performance efficiency** (%)	**Percentage of damaged fruit**
Factor A : machine speeds	1228.68*	18.39*	96.46*	522.36*	333.49*
Factor B : time of steaming	183.35*	8.44*	8.45*	78.22*	85.40*
Interaction of factor A and factor B A x B	11.33*	18.68*	5.32*	15.12*	12.44*

- Statistically significant at 5% confidence level

Table-3 shows the results of applying the Duncan Multiple Range test (DMRT) to the means of the machine speeds on the performance parameters. Table-3 showed that the feed rate (kg/h) output capacity (kg/h), stripping efficiency (%) and quality performance efficiency (%) increased with increase in the machine speeds while the percentage of damaged fruits decreased with increase in the machine speeds. This is because high machine speed influences the stripping of bunches as the necessary impact energy needed to strip bunches are produced at high machine speeds.

Table-3. Effect of machine speed on performance parameters.

Machine speed (rpm)	**Feed rate** (kg/h)	**Output capacity** (kg/h)	**Stripping efficiency** (%)	**Quality performance efficiency** (%)	**Percentage of damaged fruit**
1500	58.6[a]	54.2[a]	67.6[c]	65.4[c]	4.4
2000	64.3[b]	62.8[b]	84.4[b]	81.8[b]	1.5
2500	75.7[c]	74.9[c]	93.4[a]	91.2[a]	0.8

Table-4 shows the results of applying DMRT to the means of time of steaming of bunches on the performance parameters. It can be seen from this Table that 30 minutes of steaming of bunches (T_{30}) gave the highest stripping efficiency of (93.4%), followed by 20 minutes of time of steamy (T_{20}) (84.4%) and ten minute of steaming (T_{10}) gave the least (67.6%). The result can be attributed to the fact that steaming of bunches for a longer time weakens the bond between the fruit and bunches. Similar findings were reported by Stork (1960) in the performance of rotary drum palm fruit thresher.

Table-4. Effect of time of steaming on the performance parameters.

Time of steaming (min)	**Feed rate** (kg/h)	**Output capacity** (kg/h)	**Stripping efficiency** (%)	**Quality performance efficiency** (%)	**Percentage of damaged fruit**
T_{10}	46.2[c]	41.7[c]	63.3[a]	61.6[a]	4.5
T_{20}	58.9[b]	56.7[b]	75.2[b]	72.3[b]	2.2
T_{30}	65.5[a]	63.9[a]	79.4[c]	75.6[c]	1.6

The result of applying DMRT to the means of interaction between machine speed and the time of steaming of bunches is presented in Table-5. These results showed that interaction between machine speed and time or steaming statistically affected all the performance parameters at 5% level of significance. 2500rpm machine speed gave the best stripping efficiency, quality performance efficiency, feed rate and output capacity. At all the three investigated time of steaming 1500rpm machine speed gave the lowest stripping efficiency (53.6%), quality performance efficiency (47.8%), feed rate (46.2kg/h), output capacity (41.4kg/h) and the highest percentage of damaged fruits of (4.3%) at all three investigated time of steaming the bunches.

Table-5. Effect of interaction between machine speed and time of steaming on performance parameters.

Machine speed X time of steaming	**Feed rate** (kg/h)	**Output capacity** (kg/h)	**Stripping efficiency** (%)	**Quality performance efficiency** (%)	**Percentage of damaged fruit**
$M_1 T_{10}$	46.2^j	41.4^k	53.6^i	48.8^j	4.1
$M_1 T_{20}$	56.9^i	53.4^l	59.6^i	52.2^l	3.5
$M_1 T_{30}$	61.2^c	58.4^i	63.8^g	59.2^i	2.8
$M_2 T_{10}$	64.6^g	61.2^c	71.6^d	67.6^h	3.4
$M_2 T_{20}$	68.5^h	65.7^g	77.6^b	72.0	2.8
$M_2 T_{30}$	71.3^d	67.9^h	80.6^d	77.8^b	1.4
$M_3 T_{10}$	75.8^c	78.6^i	84.4^c	81.1^d	1.2
M_3T_{20}	79.6^b	78.7^b	88.6^b	85.6^c	0.9
$M_3 T_{30}$	81.3^a	80.9^a	91.8^a	89.4^b	0.4

4. CONCLUSIONS

a) Machine speed statistically affected the performance parameters of the machine at 5% of significance.
b) Time of steaming bunches significantly affected the performance parameters at 5% level of significance.
c) 3 .Feed rate, output capacity, stripping efficiency, quality performance efficiency increased with increase in machine speeds while percentage of damaged of fruits decrease with increase in the machine speeds.
d) 2500rpm machine speed gave the best machine performance parameters, followed by 2000rpm machine speed and 1500rpm machine speed respectively.

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