EVALUATION OF PALM FRUIT STRIPPING MACHINE DEVELOPED

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ABSTRACT

Suitable stripper that considers higher through put, efficiency, ease operation and maintenance is imperative so as to reduce time wastage and elimination the acidity on the palm fruit through fermentation method. Each samples of palm fruit bunch in eight places was heated at (1000C) temperature at time interval of 30 minutes was fed into the hopper and the stop watch was used to get the stripping time. The results of the machine's optimum efficiency and the clean fruit recovery at 30- and 240-minutes heating time with a 534.89 rpm beater speed, were 98.8 % and 94.8 % respectively. The feed rate range of the stripper (capacity) is between 18.75 kg/s and 150 kg/s which is obtained in 80- and 10-seconds stripping time respectively. The machine efficiency was 97.4%. The palm fruit sizes were affected by the heat applied on the palm fruit bunch when it's been stripped. The stripping time at the lowest time (10 sec) for 25 kg of palm fruit bunch was heated at 240 minutes and it was notes that the palm fruit not only stripped from the bunch but it was removed from the kernel due to the softness of the palm fruit increases temperature by increasing heated time as it affects the process performance of the machine when in operation.

Keywords: Palm Fruit, Palm oil, Stripping Time, Heating Time, Efficiency

1 INTRODUCTION

Palm oil (Elaeis guineensis) originated in the tropical rain forest region of West Africa, in which the main belt runs through the southern latitudes of Cameroon, Cote D'Ivoire, Ghana, Liberia, Nigeria, Sierra Leone, Togo and into the equatorial region of Angola and the Congo [1]. The palm fruit that grows on palm tree with the most common fruits grow are coconut palm fruit (Cocos nucifera) and date palm fruit (Phoenix dactylifera), açaí palm fruit (Euterpe oleracea), jelly palm fruit (Butia capitata), saw palmetto palm pruit (Serenoa repens), peach palm fruit (Bactris gasipaes), betel nut palm fruit (Areca catechu), snake palm fruit (Salacca zalacca), chilean wine palm fruit (Jubaea chilensis) and oil palm fruit (Elaeis guineensis). The fruit that grows on an oil palm tree is a bulky orange to dark red rounded fruit that grows all year round but its peak season is from February to April; it matures in compact bunches weighing up 11 to 41 kilograms (kg) or more, as well as containing more than a thousand discrete fruits alike in size to a small plum. Palms don't have leaves; instead, they have evergreen fronds that grow from an unbranched stem. Palm oil is got from the flesh of the fruit and doubtless formed part of the food source of the native populations previously recorded in history. Like most palm trees, the round fruits grow in massive clusters. Each red palm fruit has an oily flesh and oil-rich seed or kernel (Food and Agriculture Organization [2]. According to Samuel and Alabi [3], low palm oil productivity was due to poor approaches between government and the farmer in Nigeria. Although, the demand on vegetable oils is high worldwide as it is used to prevent and treat vitamin A deficiency, production of soaps, cosmetics, candles, biofuels, and lubricating greases and in processing tinplate and coating iron plates while palm kernel oil, from the seeds, are used in manufacturing edible products as margarine, ice cream, chocolate confections, cookies, bread, as well in pharmaceuticals. In addition, the cake residue after kernel oil is extracted is a cattle feed [4]. Traditional method of processing the palm fruits into oil involved the fruits bunches been stripped or threshed by separating the sterilized fruits from the bunch stalks. The drudgery, time wasting and high labor involvement gives less quality oil and the period of fermentation increases the free fatty acid content of the oil. Hence, fresh fruit bunches be processed earlier as to prevent a rapid rise in free fatty acid which normally affects the quality of the crude palm oil been produced [5]. Hence it is important that fresh palm fruits be processed on time by prevent a rapid rise in free fatty acid from affect the quality of palm oil. According to Nze et al. [6] oil palm flourishes in the humid tropics in grooves of varying density, mainly in the coastal belt between latitude 10˚N and latitude 10˚S. It is also found up to latitude in central and east Africa and Madagascar in isolated localities with a suitable rainfall. In Nigeria today, palm fruit stripping done mechanized method involved a rotating drum or fixed drum equipped with rotary beater bars detach the fruit from the bunch, leaving the spikelet on the stem [7]. These strippers are available in NIFOR, Benin Republic and Nigeria [1] while traditional method of palm fruits stripping by peasant farmers is stressful during the peak of harvest as is time consuming and ultimately results to poor quality products due to contamination the materials used with bare feet. Thus, low income output is produced by the farmers and the cost of imported strippers is often beyond the reach of the farmers. The products processed with the existing palm fruit stripper are often under-stripped with a lot of fruit fiber, thus resulting in diminished quality oil content. These strippers also have a lot of deficiency in terms of stripping time, efficiency and productivity [8]. Thus, the need to design and construct a machine that will eliminate the local method of heaping the palm fruit bunch before beating them with stick to detach the palm fruit from the bunch is important. Therefore, there is need to modify the stripper with a view to improve the efficiencies and reliability. Thus, the aim of this research is to design an electric-powered palm fruit stripping machine with locally sourced materials and having higher performance ratings than previous machines to ameliorate the challenges of small-scale palm oil farmers. Figure 1 is the palm fruits bunch, which is processing starts with harvesting the fruit bunches, chopping and stripping, sterilization, digestion, extraction, palm kernel cracking and oil extraction, and ends with oil storage with each by means of different methods and machines [9].

Figure 1. Palm Fruit Bunch [9]

The British Industrial Revolution created a demand for palm oil for candle making and as lubricant for machinery. In the early nineteenth century, West Africa farmers began to supply a modest export trade, as well as producing palm oil for their food needs, after 7 1900 European-run plantations were established in Central Africa and South East Asia, and the world trade in palm oil continued to grow slowly, reaching a level of 2150,000 metric tons per annum [10] shows the importance of palm produce to man and how most nations of the world are involved in palm oil production. Africa led the world in production and export of palm oil throughout the first half of the 20th century led by Nigeria and Zaire [11] Malaysia and Indonesia surpassed Africa total palm oil production by 1966 according to oil palm review. Published by the tropical developmental and research institute in the United Kingdom, over 3 million tons of palm oil was produced by Malaysia alone in 1983, compared with a total of about 1.3 million tons of African production [2]. In

2008, Malaysia produced 17.7 million tons of palm oil on 4,500,000 hectares of land and was the second largest producer of palm oil. As of 2009, Indonesia was the largest producer of palm oil producing more than 20.9 million tones. The bulk of oil production is provided by Indonesia and Malaysia as both produce 44 and 41.5% respectively, to the world palm oil production [1]. As of 2011, Nigeria was the third largest producer and West Africa largest producer with more than 2.5 million hectares under cultivation until 1934 Nigeria had been the world largest producer. Historically, oil palm has played an important part in the Nigeria economy [12]. However, palm oil is one of the most valuable cash crops cultivated frequently in the Southern and parts of the Middle belt in Nigeria majorly as a tropical tree crop that serve as revenue to the government and source of income for very many remote communities. The sorts of oil palm fruit take place in two forms, known as dura (with a large kernel) and pisifera (having no shell and yet sterile) while tenerais a hybrid form of dura and pisifera is the most cultivated variety because it produces fruits with higher oil content [13]. Palm oil production is very profitable and has a wide range of applications. Azam et al., [14] described the main processes of the palm oil factory as sterilization, threshing, pressing, clarification, purification, drying and storage. The picked fruits are cooked and digested into a mash which is mixed with water and agitated in a pit. Edible oil that separated and floated on the top is scooped off for clarification [15]. It was reported that highest oil extraction of 87% could be produced if fruits were processed without delay or fermentation and better-quality oil with low fatty acid and carotenoid content would be yielded. Thus, fresh fruit bunches must be processed, as soon as possible, to prevent a rapid rise in free fatty acid which normally affects the quality of the crude palm oil [16]. Low palm oil production was due to energy required in processing, over the years in West Africa, hence the gap necessitated the need to improve the designs of various palm oil processing machines to enhance productivity, achieves cost effectiveness and efficiency, ergonomics, more hygienic, conducive environmentally friendly operating conditions that pledge safety of using the machine [17]. Palm fruit stripping plays an important role in palm oil milling process. The palm fruits are processed into palm oil using either manual/traditional or mechanized/modern methods of which stripping machines are required. The two basic types of palm fruit strippers are known based on their mode of operation are the mechanically-powered stripper, which is driven by a mechanical device and electrically-powered stripper, which is driven by the use of electric motor. The palm fruit stripper is further classified into two based on their positioning as vertical stripper and horizontal stripper. Some of the existing palm fruit stripping machines are produced by many palm oil processing companies including Nigeria Institute for Oil Palm Research (NIFOR) and Faith Engineering Workshop in Nigeria (FEW). Never the less, problems linked with existing palm fruit stripping machine includes low stripping capacity, low stripping efficiency, low efficiency. Azam [14], posited that the processing of palm fruits from FFB is usually by mechanical means by use of mills indicated the important of stripping the palm fruit from the bunch immediately instead of heaping it to cause fermentation. According to Anyaoha et al. [18], work on the stripping time discovered that decrease in the mass flow rate will result to increase in the stripping time. Ologunagba et al. [5] reported that when manually operated a dual powered palm fruit stripper, the machine had an input capacity of 0.612 tons/h, stripping efficiency of 68.9 % and quality performance efficiency of 47.4 % at a sterilization time of 90 minutes. When tested with 2.25 kW electric motor at three beater speeds (450 rpm). Therefore, Table 1 showed various improvements on the stripping machine and how much levels of performance ratings they obtained. From Bello *et al*. [19] results, transport costs, high cost of plantation rentals, and poor extraction processes were most critical to inhabiting profitable palm oil processing. Idowu et al. [20] reported that to design a stripping machine, the machine must consist of hopper, threshing unit, drive mechanism, separation unit, discharge outlets and electric motor. Thus, the sterilized spikelet put into hopper will have a direct contact with a revolving beater lined with rubber to reduce spoiling the fruits by mechanical pressure. Impact forces generated by the beaters separates fruits from spikelets and push them to bottom chamber after screen, while the spikelet bunches go to the other discharge outlet. The works of Onifade et al. [21] and Adepoju et al. [22] agreed with improving design pattern in stripping gives efficiencies on various input and output capacities differed. However, these hardly met the demands of farmers in rural communities. Palm fruit stripping machine come in various shapes considering design in Figure 2 shows research on the challenges of stripping, model designs and material requirements with aim to improve upon existing stripping machines.

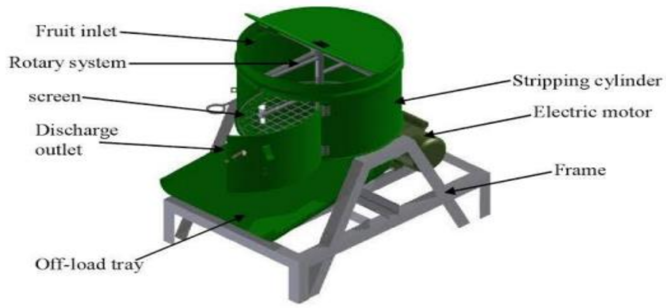

Figure 2. A small-scale Palm Fruit Stripping Machine [21]

These strippers have deficiency in terms of stripping time, efficiency and productivity (Table 1). There is need to modify the stripper with a view to improving their efficiencies and reliability. In view of this, there is need to improve on the existing design of a palm fruit stripping machine for higher efficiency and higher production rates at low cost and with locally available materials that allow for easy operation and maintenance.

Table 1. Performance Results of Previous Stripping Machines

S/N	Average Weight of Bunches (kg)	Stripping Time (s)	Efficiency (%)	Input Capacity (kg/s)	Stripping Capacity (kg/s)	Clean Recovery (%)
1	38.70	89.67	98.91	150.18	256.72	96.03
2	29.5	129.15	62.35	92.90	330.91	
3	35.4	160	98.71	346.84	227.47	98.52
4	32.7	152	93.00		769.25	

source: [20, 21, 22, 23]

2 MATERIALS AND METHOD

The materials: mild steel was selected for the fabrication of component parts of the machine, welding machine, angle irons, oxygen acetylene gas, drilling machine, tri square, hack saw, vice and electric hand grinder are some of the equipment's used during the fabrication of the machine. However, AutoCAD was considered to bring out detailed 3D drawing design of stripping palm fruit using electric motor to power other engineering properties of the machine itself was considered. The knowledge of sizes, shapes and weight of the machine in terms of length, width, thickness and diameter are all essential and needed in the design of agricultural machines. Some of these properties have been taken into considerations. The physical properties to be consider for the fabrication includes impact strength, ductility, machinability, toughness, wear resistance and corrosion. The design of the machine made it possible for various part of the machine such as the hopper, frame, belt and the electric motor of the machine to be easily dismantled and coupled aid easy transportation.

2.1 Performance Evaluation of the Stripping Procedure

Matured palm fruits bunch of Eight different weight was procured from a farmer located at Southern Kaduna, Nigeria precisely Zango-Kataf with latitude: 9.84111 and longitude: 8.25590 50' 28''. Each of the samples were weigh and adjusted to have 25 kg for each palm fruit bunch. Each sample (which is the palm fruit bunch) was heated at (1000C) temperature at time interval of 30 minutes. Each palm fruit bunch sample was fed into the hopper and metered at 80sec, 41sec, 27sec, 21sec, 17sec, 14sec, 12sec and 10sec using one stop time at a time. The quantity of palm fruits that was stripped from the bunch and came out through the hopper outlet was weigh using weighing scale (Mettler Toledo PB 153 electronic balance, Mettler Toledo GmbH, Greifensee, Switzerland). Using below equations, the performance of the palm fruit stripping machine was tested by determining the stripping capacity (Kg/s) and efficiency, η (%) [24].

$$\text{Sc} = \frac{w \times 60}{Ta} \quad (1)$$

Where, Sc = the stripping capacity (kg/s), W = the initial weight of palm fruit fed into the stripper. Ta = the average stripping time (s).

$$\eta = \frac{Ws}{w} x\ 100 \quad (2)$$

Where, η = Efficiency (%), Ws = Weight of the stripped fruit collected in the outlet of the stripper (kg), w = Initial weight of the palm fruit (kg). Using above equation, efficiency of the machine can be determined by calculate the mean or average of the performance. However, the stripping time and the efficiency at various time for heating for the above process was recorded. The following parameters were then computed and tabulated in Tables 2 and 3 are weight of the palm fruit bunch (kg), heated time (minute), stripping time (sec), weight of stripped palm fruit (kg), stripping capacity (kg/s) and efficiency (η) respectively.

3 RESULTS AND DISSCUSSION

The machine was designed after computing the necessary size (s) of each part. The following were the results of the designs shown in Table 2.

Table 2. The Value of the Parameters of the Machine

Parameters	Values
Height of Hopper	596 mm
Volume of Hopper	117030500 mm^3
Diameter of motor pulley	80 mm
Length of Belt	153284 mm
Efficiency of the Machine	97.4 %
Mass of Palm fruit bunch	25 kg
Mass of Flanges	0.051 kg
Diameter of size reduction unit shaft	25 mm
Mass of beater	0.85 kg
Power required to drive the shaft	2.6 kW
Machine Torque	45.07 Nm

3.1 Performance Evaluation of the Stripping Operation using Effect of the Heat on Stripping Time and Palm Fruit Size

The palm fruit sizes were affected by the heat applied on the palm fruit bunch when it's been stripped. The stripping time at the lowest time (10 sec) for 25 kg of palm fruit bunch was heated at 240 minutes and it was noted that the palm fruit not only stripped from the bunch but it was removed from the kernel due to the softness of the palm fruit. As shown in Table 3 increase in stripping time is as a result of decrease in the heat applied.

Table 3. Heat Applied at various Time for Constant Weight of Palm Fruit Bunch and different Stripping Time

S/N	Weight of Palm Fruit (kg)	Heating Time (min)	Stripping Time (sec)
1	25	30	80
2	25	60	41
3	25	90	27
4	25	120	21
5	25	150	17
6	25	180	14
7	25	210	12
8	25	240	10

Figure 3. showed that the stripping time of the designed stripping machine has a direct relationship with boiling time although, stripping time increased more from 60 mins of the boiling time.

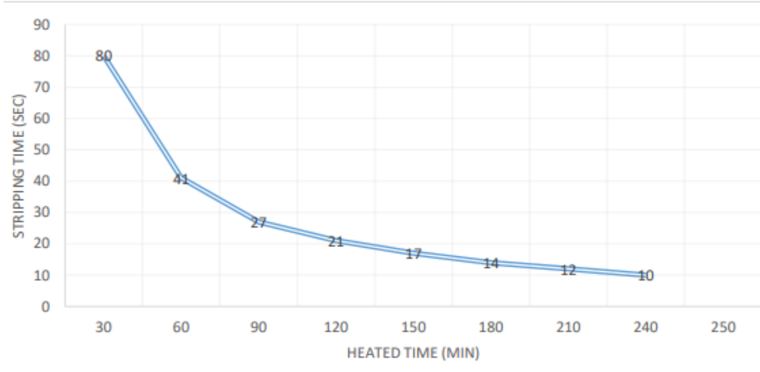

Figure 3. Relationship between the heated time of the palm fruit and stripping time

3.2 Effect of Weight of the Stripped Palm Fruit on Stripping Efficiency

Table 4 shown the performance ratings obtained from the test experiments of the designed and fabricated palm fruit stripping machine however, Table 4 and Figure 4 showed that with increasing heated time, the stripping capacity was increasing which is in line with results of Idowu *et al.* [20] on high throughputs because the energy required for stripping reduced with increasing heated time was subjected to weak bond within the palm fruits. Hence, the increasing stripping capacity ranged between 18.75 kg/s and 150.00 kg/s from boiling time of 30 mins to 240 mins indicates arithmetic in progression. Table 4 showed that increasing heated time increased the stripping efficiency. Idowu *et al.* [20] informed that prolonged boiling resulted in higher efficiencies. The results were such that as heated time increased from 30 to 150 minutes the efficiency increased with an efficiency of 98.80 %. At boiling time of 30 minutes its efficiency peaked at 98.90% but dropped at 240 minutes to 94.8%. This fluctuating behaviour because of interference from the spikelets to vibratory forces. Onifade *et al.* [5], Idowu *et al.* [20], Oshiobugie *et al*. [21] and Ologunagba *et al.* [23] also obtained higher efficiencies above 90 % because of the weakened bonds between spikelets and palm fruits, and reduced stripping energy facilitated by boiling time. Hence, the increasing stripping efficiency ranged between 98.80 % and 94.80 % from boiling time of 30 mins to 240 mins. Comparatively, the performance ratings of this research were appreciably much better when the results of Table 1 were compared with Table 4.

Table 4. Computing the Weights of Palm Fruit Bunch, Stripped Palm Fruit, Heated Time, Stripping Time, Stripping Capacity and Stripping Efficiency

S/N	Weight of Palm Fruit (kg)	Weight of Stripped Palm Fruit	Boiling Time (min)	Stripping Time (sec)	Stripping Capacity (kg/s)	Stripping Efficiency (%)
1	25	24.70	30	80	18.75	98.80
2	25	24.70	60	41	36.60	98.80
3	25	24.90	90	27	55.60	98.80
4	25	24.70	120	21	71.40	98.80
5	25	24.70	150	17	88.20	98.80
6	25	23.90	180	14	107.10	95.60
7	25	23.70	210	12	125.00	94.80
8	25	23.70	240	10	150.00	94.80

The effect of heat applied on the time required to effectively strip an FFB shown in Figure 4 escribed a polynomial behavior but according to Azam *et al.* [14] prolonged boiling initiates a weakening of the bonding in each fruit facilitating a shear force large enough to pull and tear through its mass. Hence, increasing temperature by increasing heated time affects the process performance of the machine when in operation, hence speeded up the stripping which will scatter the palm fruit from the kernel. From Table 3, the stripping time indicated a marked decrease for every increase in heated time however, the behaviour was best expressed in Figure 3 where the relationship was an inversely proportional compare with Idowu *et al.* [14]. Azam *et al.* [20] had informed that boiling reduces stripping time because sterilization is done to deactivate hydrolytic enzymes which inhibit free fatty acids formation. Hence, the testing showed that the more the boiling time, the more the weakening of bonds in the fruits and thus making stripping of the palm fruits relatively easier. Therefore, in all the test carried out, at 30, 60, 90, 120, 150, 180, 210 and 240 minutes boiling time and 540 rpm beater shaft speed, the stripping time; the stripping capacity and stripping efficiencies as indicated in Table 3 showed a remarked improvement when compared with Table 1 which is the previous stripping machines performance ratings.

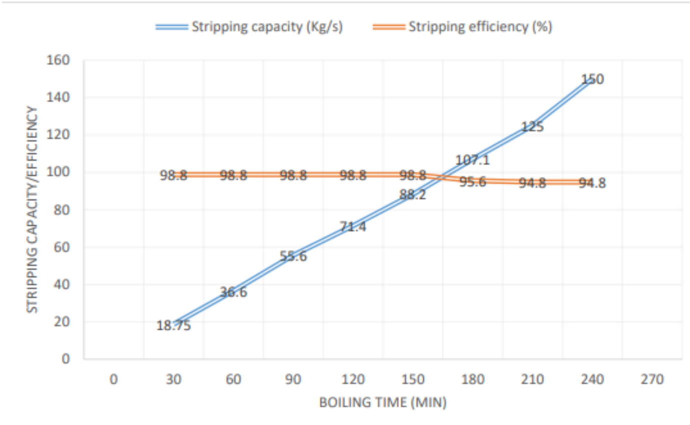

Figure 4. Relationship between the heated time of the palm fruit bunch and stripping capacity/stripping efficiency

4 CONCLUSIONS

The performance evaluation, the performance test results and the stripping time generally decreased with increased time of heat. The values of the optimum heated time (240 minutes) obtained after various tests at varying heating periods were stripping efficiency, stripping capacity and stripping time, respectively, 98.8%, 150.0 kg/sec and 10 sec. While the stripping efficiencies from boiling times of 120 to 240 minutes were consistent at 98.8%, the lower boiling periods yielded between 94.8 to 95.6%The stripping design part gave the greater work performance at 30 minutes heated time rate can help solve the associated problems and difficulties of palm fruit stripping especially for small- and medium-scale oil pam farmers with scattering the palm fruit when stripped. Therefore, it can be conclusively stated that an electric-powered palm fruit stripping machine pose improvements to the machine fabricated.

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