THE DESIGN AND FABRICATION OF A BATCH PALM KERNEL DIGESTER AND PRESSING MACHINE

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Abstract

The high demand in oil palm for local and international consumption cannot be met by traditional method of extraction which are solely in the hands of peasant rural women. This has made it necessary to design and fabricate an easy to use palm kernel digester that is powered by a gasoline engine to remove drudgery in oil palm processing. This makes this design suitable in rural area where electricity is scarcely available and in urban areas where power supply is erratic. This design consist mainly of five major components which include; hopper, worm shaft, combustion chamber, pressing unit and a mild steel firm support. The volume of the feed in hopper was determined from the geometry and this gave an estimated of mass of palm kernel that could be digested per time or in a batch. The digester was runs on a gasoline engine of 13hp after careful consideration of density of palm kernel with appropriate speed of worm shaft. The key part of the machine include; digester, screw press design, and lagging materials the press chamber, and the cylindrical barrel housing of the machine were carefully and properly assembled. A weighted sample of 6.5kg palm kernel fruits was feed in through the hopper and mash or digested fruit of 1.62 kg was obtained. The digested or mash of oil palm was pressed using screw press. The crude oil obtained was 1.22kg is further fractionated to separate oil from non-oil. The efficiency of the design was estimated as 75.31% and the ratio of the edible palm oil to the crude palm oil was 0.75. The design of a batch palm kernel Digester and pressing machine have significantly improve ease of extracting oil from palm kernel fruits, thereby putting more money in the hands of the peasant locals and drastically reduce intensive labour and it is an advancement over the traditional method.

Keywords: Design, fabrication, palm, kernel, digester, pressing, machine

Introduction.

Oil Palm (Elaeis guineensis) originated in the tropical rain forest region of West Africa. The main belt runs through the southern latitudes of Cameroon, Côte d'Ivoire, Ghana, Liberia, Nigeria, Sierra Leone, and Togo and into the equatorial region of Angola and the Congo. Processing oil palm fruits for edible oil has been practiced in Africa for thousands of years, and the oil produced, highly coloured and flavoured, is an essential ingredient in most of the traditional West African cuisine [1]. About 90 percent of the palm oil produced ends in food products, while the remaining 10 percent is used for industrial production [2]. According to [3] described oil obtained from palm kernel as highly beneficial to human. It provides supplies nutrients such as vitamin A and the fat that keeps the body warm. After harvesting the crop, the next stage in the processing line is extraction of oil from the fruit. According to [4] they define extraction as the process of recovering oil from oil-bearing agricultural products through manual, mechanical, and chemical process. The oil content of the palm fruit was estimated as 30 per cent by weight of the fresh fruit bunch as quoted by [5].

Adekola [6] reported that the yields and quality of the oil extracted depend on the content adjustment, heating time, pressure application, operating temperature, and even the species that was under investigation.

Nigeria is currently the third largest producer of palm oil in the world after Indonesia and Malaysia. Palm oil extraction process and other agricultural related products in Nigeria during pre-independence era and post-independence offer the highest employer of labour to both skilled and unskilled workforce. This is helping to improve living standard amongst Nigeria [7].

The demand for local consumption of oil palm has continue to increase owing to rapid growth recorded in population size in the country. Nigeria population is conservatively estimated as 190 million. Similarly, global consumption rose from 14.6 million tons in 1995 to 61.1 million tons in 2015, making it the most consumed oil in the world. The main consumers of palm oil are China, India, Indonesia and the European Union. India, China and the EU do not produce crude palm oil and their demand is entirely met by imports. In 2015, India, China and the EU accounted for 47.9 per cent of global imports [8].

In most of the developing countries, there has been a steady rise in the demand of edible oil both for domestic and industrial uses. Therefore, continuous review of existing methods of oil extraction from oil-bearing agricultural products like palm kernel fruits has clearly shown that traditional method of digesting and extracting oil from palm kernel fruits is grossly inadequate to meet domestic demand, industrial uses, as most researchers described this method as laborious, unhygienic, time consuming etc It is to this end that this work has been conceived. To design and fabricate a mechanised digester and a pressing machine that will eliminate the drudgery experienced in the use of traditional method which are in use by peasant rural women. The design of a digester and pressing machine is a simple easy to use machine powered by a gasoline engine. The choice of gasoline engine is as result of erratic power supply from national grid either in rural or urban areas.

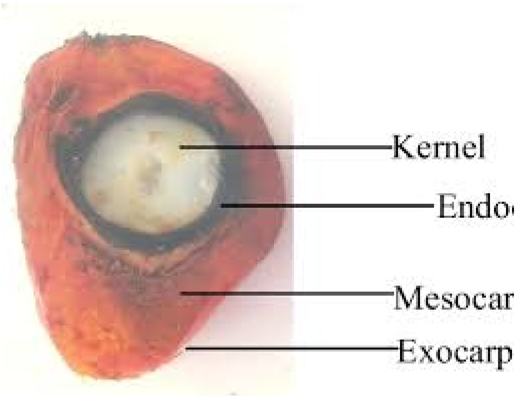

Figure 1: Structure of a palm kernel fruit.

2.0 Methods of Extracting Oil.

In this section two methods of extraction will be discuss briefly;

2.1.1 Traditional method

The traditional method is simple, it involves the use of bare foot or mortar and pestle to digest oil from fresh fruits bunch. This methods was described by different researchers [7] and [9] as tedious, time consuming, laborious, hazardous and inefficient resulting in the production of low quality oil which is inadequate in meeting desired quality and quantity of oil needed for local consumption and for global sales.

2.1.2 **Mechanical Methods**

Okafor [5] developed an oil palm digester with materials made from local sources. He incorporated lag materials in the design to prevent temperature drop as it was critical to the efficiency of the design. He considered the performance of the oil extractor at. $92^0C, 96^0C$ and 98^0C. Percentage of oil extracted was highest at 98^0C similarly, Fashina, Durdola and Hameed (2017) constructed an oil palm digester made from locally sourced materials, the machine digested Fresh Fruit Bunch and attained a throughput capacity and efficiency of the machine was 330.91kg/hr and 62.35% respectively.

2.2 Design Consideration

2.2.1 Volume of the hopper

$V_a = l \times b \times h$ --------(1)

=0.2286 x 0.3048 x 0.2286

= **0.01593 m^3**

$V_b = l \times b \times h$ = 0.3048 x 0.4572 x 0.0762

= **0.01062 m^3**

$V_c = \frac{1}{2} x(i\ x\ j\ xk)$------(2)

$= \frac{1}{2}\ x\ (0.3048\ x\ 0.2286\ x\ 0.254)$

= **0.008849m^3**

$V_T = V_a + V_b + V = V_a + V_b + V_c$--------(3)

= 0.01593 + 0.01062 + 0.008849

= **0.02832m^3**

Speed of the driven pulley, N_2

d_1=0.1016m, N_1=2600rpm, d_2=0.3048m

N_2d_2=N_1d_1

$$N_2 = \frac{N_1 d_1}{d_2} = \frac{2600 \times 0.1016}{0.3048} = 867\text{rpm}$$

$\omega_2 = \frac{2x\pi x N_2}{60}$ = **90.79rad/s**

2.2.2 Speed ratio.

N_2= 867rpm, N_1 = 2600rpm, d_2= 0.3048m

d_1= 0.1016m.

$$r_s = \frac{N_1}{N_2} = \frac{d_2}{d_1} \text{----------(4)}$$

$$r_s = \frac{N_1}{N_2} = \frac{2600}{876} = 3$$

$$r_s = \frac{d_2}{d_1} = \frac{0.3048}{0.1016} = 3$$

2.2.3 Design for shaft with consideration for gradually applied load

$$M_e = \frac{1}{2}\left[K_m \times M + \sqrt{(K_m \times M)^2 + (K_t \times T)^2}\right]$$

-------- (5)(Khurmi and Gupta, 2006)

K_m = combine shock and fatigue factor for bending = 2.0

K_t = combine shock and fatigue factor for torsion = 2.0

M= bending stress and T= torsional stress

Maximum bending stress for a Uniformly Distributed Loads

$$M = \frac{WL^2}{8} \text{------------(6)}$$

$$= \frac{1500 \times (0.8)^2}{8} = 112 N - m$$

$$T = \frac{P \times 60}{2\pi N} --------(7)$$

$$= \frac{10 \times 10^3 \times 60}{2\pi \times 873} = 109.4 N - m$$

$$M_e = 2.0 \times 112 + \sqrt{(2 \times 112)^2 + (2 \times 109.4)^2}$$
$$= 224 + \sqrt{50176}$$
$$= 224 + 313.128$$
$$= 537.13\text{N-m}$$

$$M_e = \frac{\pi}{32} \times \sigma_b \times d^3 ------(8)$$

$$537.13 = \frac{\pi}{32} \times 45 \times 10^6 \times d^3$$

$$537.13 = 4.418 \times 10^6 d^3$$

$$d^3 = \frac{537.13}{4.418 \times 10^6}$$

$$d^3 = 121577 \times 10^{-4}$$

$$d^3 = \sqrt[3]{121577 \times 10^{-4}}$$

$$d = 0.049539m \approx 0.050m$$

$$= 49.5mm \approx 50mm$$

2.2.4 Design Consideration for the compression chamber

The choice of material selected was stainless steel with high resistance to corrosion, good strength and high impact value to withstand the pressure the chamber would be subjected to while in use.

3.0 Materials

A weighing scale; this was used to measure the weight of fresh fruit bunch before introducing the fruit into the machine. The fluid obtained from the combustion chamber is also weighed and after heating the fluid to separate oil from water. The oil is weighted to note the quantity of oil obtained from the process

3.1Methodology

The machine consist of five major parts which include; hopper, gear box, worm shaft, compression chamber and a mild steel support base. Stainless steel and mild steel materials were selected for this design. The stainless steel was used to design parts of the machine wherein the palm kernel fruit would be processed so as to avoid food poisoning, while mild steel was used to provide a firm support to the machine. The materials were measured using tape rule, meter rule and scriber before using guillotine cutting machine to cut the required size from the buck materials. A stainless of 60cm by 30cm was bend to house the gear reduction system which was connected to a prime mover of 13 h.p gasoline engine. The gear box was synchronised with the worm shaft made of stainless steel which was 80cm in length. Connected to the screw shaft is a small compartment called compression chamber. The compression chamber is rectangular in shape dimensioned as 20cm by 34 cm, made of stainless steel material. The compression chamber has a small square opening below to allow compressed oil to be collected, while another collecting point for the pressed chaff. A manual screw jack is attached to the compression chamber to squeeze the oil from the mash or digested oil.

3.2 Assumption.

- The steamed fresh fruit bunch was steamed or heated to $98^0 C$. It was assumed that all through the time taken by the machine to digest the fruit, the temperature remains constant or unchanged.
- Weight of palm kernel fruit before digestion equals the weight of oil extracted, non-oil and palm kernel after digestion.

4.0 Result and Discussion

4.1Results

Mass of palm kernel fruits m_1 (Kg)	Mass of digested oil from the machine m_2 (Kg)	Mass of oil extracted after m_3 (kg)	Mass non-oil extracted m_4 (kg)	Mass of kernel after digestion m_5 (Kg)
6.50	**1.62**	**1.22kg**	**0.40**	**4.88**

Figure 2: Result obtained from digestion of palm kernel fruits

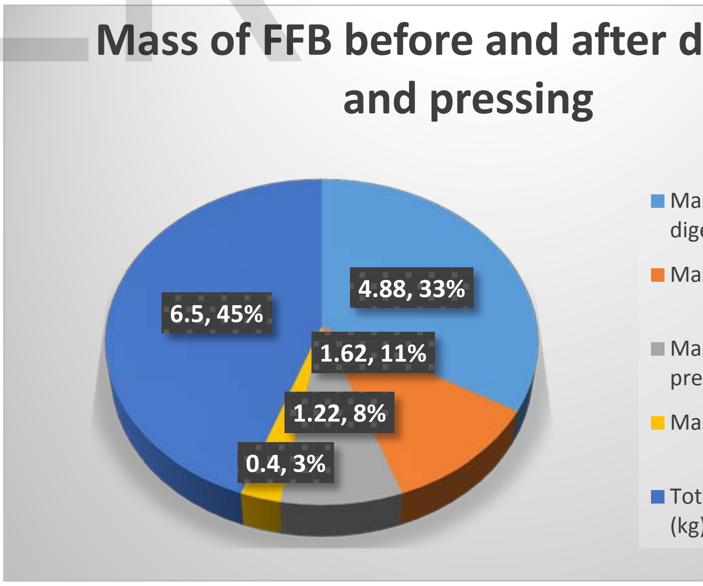

Figure 3: Mass of palm kernel fruit before and after digestion

$$Efficiency = \frac{m_2 - m_4}{m_1 - m_5} \times 100 - - - - - - - - (9)$$

$$= \frac{1.62 - 0.40}{6.50 - 4.88} \times 100$$

$$= \frac{1.22}{1.62} \times 100$$

$$= 75.31\%$$

$$\text{Throughput capacity of the machine} = \frac{\text{mass}\,(m_1)\,Kg}{\text{Time taken hr}} \quad 10$$

$$= \frac{6.5\text{kg}}{\frac{10}{60}}$$

$$= \frac{6.5\text{kg}}{0.1666}$$

$$= 39.0\text{kg/hr}$$

4.2 Discussion

6.5kg of palm kernel fruits were boiled at a temperature of about 98^{0}C. The Palm kernel fruits digesting and pressing machine was test run in order to determine its performance. The digester and pressing machine was manned a person. The 6.5 kg was introduced into the machine through the feed-in hopper. The palm kernel fruit was allowed to digest in about 10 minutes from the time it was fed in. The digested/ mash oil fruits were collected in the compression chamber The crude palm oil extraction efficiency of the screw press, that is, the ratio of the quantity of crude palm oil extracted to the quantity of palm kernel fruits fed in. The machine was connected to a 13HP petrol engine, the sterilized palm kernel fruits at a temperature of 98^{0}C were loaded into the machine through the feed-in hopper where they were digested and pressed to give a crude palm oil output. The quantity of crude obtained was found to be 1.62 Kg. The crude palm oil was subject to boiling in order to extract edible palm oil from it. The quantity of edible palm oil extracted was found to be 1.22Kg.

With the above data, the crude palm oil extraction efficiency of the screw press, that is, the ratio of the quantity of crude palm oil extracted to the quantity of palm kernel fruits fed in was 75.31%. This value differs by 5% from the figure quoted by (Okafor 2015). This could be either be adduced to the different species of fresh fruit bunch under investigation or subjecting it to different conditions.

The ratio of pressed edible oil to the crude palm oil was found to be 0.75 while the throughput capacity of the machine is 39.0 kg/hr. This implies more fresh fruit bunch can be processed which is an improvement over traditional method.

5.0 Conclusion

A palm kernel fruits digesting and pressing machine was designed, constructed and tested for palm oil extraction. The digesting and pressing machine was simple enough for local fabrication, operation, repair and maintenance. This machine is powered by a 13hp petrol engine, this makes it suitable in rural area where there is no supply of electricity and in urban areas where electricity supply is epileptic. The machine has an average crude oil efficiency of 75.31% and a ratio of edible oil to crude oil of 0.75. The digesting and pressing machine can be used for small scale palm kernel oil extraction in the rural and urban communities.

6.0 Benefit of the Machine.

1) More fresh fruits bunch can be processed with minimal human effort
2) Oil produced from this machine is done in hygienic way and free of contamination or corrosion
3) With this machine in place, rural women will be able to meet local demands and industrial uses of palm oil.
4) Post-harvest losses by farmer would be eliminated as oil extraction that constitute bottleneck in oil processing line has been removed.

7.0 Recommendation.

1) A lag material should be incorporated into the screw shaft compartment to maintain the temperature of boiled palm kernel fruit.

2) The use of human effort in pressing should be replaced with a simple/automated machine.

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Reference

1.FAO. (2005) Small-scale Palm Oil Processing in Africa. Food and Agricultural Organization (FAO) AgriculturalSeries148.pp.1-55. http://www.fao.org/document/show_edr.asp?urlfile=/DOCREP/005/Y4355E/Y4355E03.htm (Accessed: 2005).

2.Babatunde O. O. (1987). Sterilization and Mechanical Digestion of Oil Palm Fruit, Obafemi Awolowo University, Ile-Ife, Nigeria, Ph.D Thesis.

3.Cottrell, R.C. (1991). Introduction Nutritional Aspects of Palm Oil. *American Journal of clinical nutrition* 53: 989S – 1009S.

4.Ibrahim A and Onwalu A.P. (2005). Technologies for Extraction of Oil from oil Bearing Agricultural Products: A Review. Journal of agricultural Engineering and Technology vol 13 pp58-89.

5.Okafor B.E. (2015). Development of Palm Oil Extraction System. International Journal of Engineering and technology Vol. 5 No 2 pp 68-75

6. Adekola, K A. 1991. Process optimization of oil expression from coconut (cocosuncifera L). An M. Sc. Thesis submitted to Department of Agric. Engineering, University of Ibadan, Nigeria. NSAE Proc. 16: 102-11.

7. Owolarafe O. K., Faborode M. O., & Ajibola O. O. (2002). Comparative evaluation of the digester-screw press and hand-operated hydraulic press for oil palm fruit processing", *Journal of Food Engineering, U. K.*, Vol. 52, PP. 249–255.

8. EU (2016) Palm Oil Alliance Balanced and fact based. The Palm Oil Story Fact and Figures. www.palmoilandfood.eu

9. Fashina A.B., Durodola O.S., and Hammed I.A. (2017). Development and Performance Evaluation of an Oil Palm Digester. Bioprocess Engineering journal 1(2) 49-53.

10.Khurmi R.S. and Gupta J.K. (2006). Machine Design. Eurasia publishing house (PVT) Limited.

Figure 4: palm oil digester and pressing machine.