Development and Performance Assessment of an Improved Palm Oil Digester

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ABSTRACT: ***Palm oil unavoidable uses such as edible oil, soap, margarine and so on has led to the needs of more efficient, mechanized and automated method of processing palmfruits to substitute the traditional and crude methods of digesting palm fruits, with its bulk of demerits ranging from low production capacity, hygienic nature, large consumption of time and energy. The faculty of Agriculture farm in Ekiti state university needs this palm fruit digester to assist the facilitation of farm produce processing, to increase internal revenue, provide employment opportunities and reduce rural-urban drift and its consequences. This design was based on series of experiments especially on the basic raw material –palm fruits to ascertain its physical properties, which aided in the determination of the machine's capacity, power requirements and other design considerations. The constructed palm fruit digester was heater in a laboratory and field tested and the functional level was found to be satisfactorily. This machine has a digesting capacity of about 620kg in one hour and an efficiency of 62.23%. The cost estimation of the machine is comparatively cheap and affordable by small scale entrepreneur.***

Keywords*: capacity, digester, efficiency, machine, palm fruits.*

I. INTRODUCTION

The need for palm oil and other palm kernel products has increased geometrically making it very essential to improve on palm oil processing techniques, most especially the most stressful part, digestion. Agriculture is one of the important sectors of a country like Nigeria. For a rapid or sustained economic development to take place, there is a vital need for developed agricultural sector [1]. The provision of modern facilities locally at cheaper rates will lead to increase productivity in agriculture which will enable processors and consumers benefit from the supply of oil palm produce at the right time and in sufficient quantities. The oil palm has contributed immensely to the economy and had placed Nigeria in a leading position of palm produce exporters of the world before the advent of oil boom [2]. The shortages and importance of palm oil over the years in West Africa in particular, and other parts of the world where the production of the oil normally takes place has necessitated the need to improve upon the design of the palm oil machine, the most important of the components of which is the palm oil digester. Oil palm is a valuable crop because of its major products (red palm oil and white palm kernel oil). Palm oil is of considerable commercial importance. About 14% of world's supply of vegetable oil is derived from oil palm [3]. The extraction of vegetables and edible oil seeds such as groundnuts, kernels, copra, palm fruit, is a well-established industrial activity in a number of developing West African and Asian countries like Senegal, Liberia, Cameroon, Sierra Leone, Nigeria, Malaysia and Indonesia. Nigeria used to be one of the highest producers of palm fruit until the discovery in 1958 of crude oil in the southern part of the country [4]. This diverted attention from agricultural production, which used to be the main stay of the economy [5]. The Oil Palm (Elaeisguineensis) is traced to have its origin from the tropical rain forest region of West Africa; this vegetation is found around Cameroon, Cote d'Ivoire, Ghana, Liberia, Nigeria, Sierra Leone, and Togo and the equatorial region of Angola and the Congo. The palm fruit nut is made up of an outer skin (epicarp), a pulpy skin (spongy mesocarp) containing the palm oil in fibrous matrix, central nut consisting of stony shell carp and the kernel which itself contains palm kernel oil [6].The palm fruit digester is the farm processing machine in which its mode of operation is quite similar to that of rotary machines. The beater shaft is revolved due to beating action, palm fruits are crushed into somewhat homogeneous mass of palm nuts and fibre containing oil [7].

Local palm oil production has stages, after local heating/boiling in drums, digestion of palm fruit nuts is usually performed by the use of mortars and pestles or by barefoot mostly by women and young men. This has been on before the advent of locally fabricated machines like palm kernel cracker, digester etc.

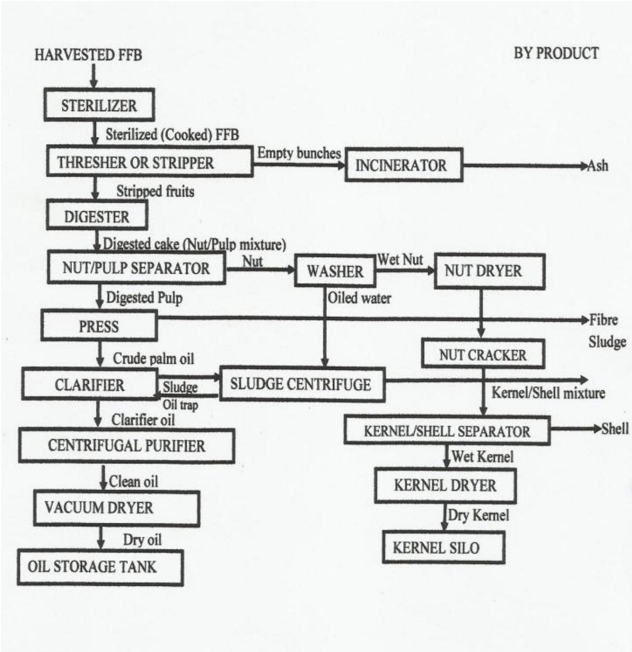


Figure 1.1 Palm Oil Processing [1]

Digester is the major consideration in this project because it is the most stressful stage in palm oil processing. The oil palm is an erect single stemmed tree of fairly uniform column growing up to eight meters or more at maturity. The ovary inflorescence develops large bunches and each bunch contains approximately between 800-1000 fruits [8]. The size of the fruits or the nuts depends mainly on the thickness of the shell. Because of its economics importance as a high yielding source of edible oils, oil palm is now grown as a plantation crop in most countries with high rainfall (minimum 1600mm/year). The palm bears its fruits in bunches varying in weight from 10 to 40kg. The individual fruits are made up of an outer skin (exocarp), a pulpy skin (mesocarp) containing the palm oil in fibrous matrix, central nut consisting of shell carp) and the kernel which itself contains oil quite different from palm oil. The fruit is an ovalshaped drupe 2.5- 5cm in length and 2.5cm in diameter. The fruits are borne tightly clustered in large bunches which may weight from 5kg in young pour palms to as much as 40kg in 15-year-old palms in favourable condition [8].

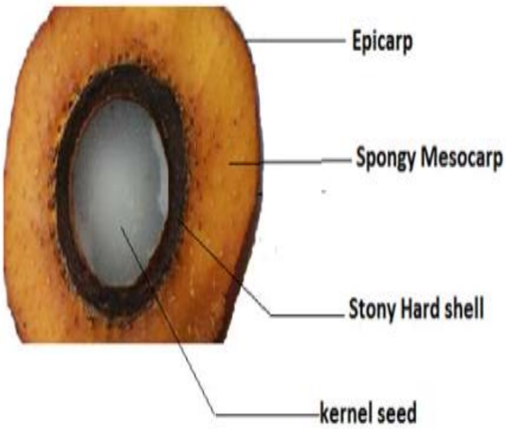


Figure 1.2: Palm Fruit

The primitive methods of processing palm oil are usually characterized by slow and very low digestion, production rates, time-consuming, and drudgery and the fact is that a lot of human energy is usually expended during digestion even if it is termed unhygienic. To overcome problems associated with primitive methods, machines were designed. The designed machines were faced with lubrication of the rubbing parts in which only grease is being used. Other efficient methods can be taken. With lighter oil in the gear, the speed will increase and the efficiency will increase because the wear at the gear teeth will be reduced. With the provision of mechanism for the adjustment of tension at the belt, there will be increase in the life span of the belt. Each part will be detachable for easy maintenance and the machine will be moveable without any external transport factor from one farm to another.

This project doesn't go beyond assessing an existing Palm oil digester, designing an improved palm oil digester, constructing the improved palm oil digester and carrying out performance evaluation on the improved palm oil digester.The significance of the study is to provide information about the local production of palm oil digester which will be beneficial to local fabricators, engineers and agricultural processing industries and to improve on the local methods of processing palm oil.The improved digester will ease the production of palm oil and it will be a basis for research and modification in the field of Engineering. Also, the designed machine will be used in the laboratory for other experimental analysis. The Palm oil digestersare machine that perform the work of digestion of palm oil. Digestion involves the meshing up of the fruits under steam-heated conditions and pressing out the crude palm oil. There are different types of digesters: The beaters digesters and Screw digesters. The beaters types comprise shaft with beaters which digest boiled palm nuts to remove the oily spongy mesocarp from the kernel through collision and squeezing. The beaters types are also group based on the positioning of the shaft. Two types of digesters were developed: horizontal digesters based on the dry process technique; and the vertical digester, which adopts the wet process technique. There is a vertical shaft with augers or beaters and those of the horizontal shaft with auger or beaters. However, the locally available are vertical shaft, batch production machine with one or two through puts. In the wet system, sterilized fruits are poured into the digester. As the fruits are being macerated, hot water is continuously poured into the digester (at a regulated rate) to wash off the released oil. The resultant mixture of water and oil is filtered and then clarified [12].Another attempt at mechanizing the maceration process resulted in the development of the manual digester for women. This digester consists principally of a large wheel (connected to the differential system of a car axle), and a vertical shaft carrying some beater arms that rotate inside a conical shaped metal trough. The ratio of rotation of the wheel to the vertical shaft is 1:7. It takes between 12 and 15 minutes to digest a 30 kg load of fruit.The mechanical digesters currently in use consist of a cylindrical shell and a system of beater-arms driven by a 6 hp. diesel engine through a speed reducer (where necessary). The speed reducer steps down the speed of the motor (engine) to 125 rpm - the running speed of the digester. The digester is capable of macerating over 250 kg of fruits per hour and has the singular attribute of macerating thoroughly either the Dura or Tenera fruit or a combination of both without breaking any nut. Beater shaft is revolved through the pulleys and V belts by 5

HP electric motor or 6 HP diesel engine. So due to beating action, palm fruits are crushed into somewhat homogeneous mass of palm nuts and fibres containing palm oil. This mass is discharged from the bottom outlet of the other end of the machine. Pounding machine is also called palm fruits digester [13].Generally, twin-screw press is used to extract the oil from the digested mesh. The crude oil is further purified and dried for storage. The solid wastes from the milling operations are empty fruit bunches, palm fibres, and palm kernel shells [14].The oil palm fruits digester comes in two categories and these are vertical and horizontal digesters [15]. In a vertical digester, digestion of fruit mesocarp is done by a vertical shaft fitted with beater arms at specified orientation and spacing on the shaft; while in horizontal digester, digestion is done by the beater arms which also transport macerated fruits from the digester inlet to the outlet [16]. Palm oil processing flow chart is conceptualized as this is based on the technology involved and the understanding of the study.

II. MATERIALS

The strength durability and service of a farm implement depend largely upon the kind and quality of material used in building it. There is a tendency in the construction of Implements to eliminate as many castings as possible and to use pressed and stamped steel. Where this is done, the cost of manufacturing machinery in quantities is materially used in building it. The materials used in the construction of farm implement may be classified as metallic and non-metallic [4]. The metallic is further divided into ferrous and non-ferrous materials. The non-metallic materials are wood, rubber, leather, vegetable fibres and plastics. The non-ferrous metals are copper and its alloys (such as brass and bronze) Aluminium, Magnesium, Lead, Zinc, and Tin [17]. Welding processes can be broadly classified under Gas welding, Arc welding, Resistance welding and Electron Beam welding. In this fabrication, we made use of electric arc welding.

2.1 METHODS

The design for the development of the continuous boiled-palm kernel nuts digesting machine began by developing the concept with computer aided design(CAD) - a virtual design was done with autoCAD2017. The design was followed with design and material selection considerations.

Design Consideration

The functional parameters and component parts that were considered in this work are:
a. Density of boiled palm nut
b. Machine pulley speed: This deals with the time factor to digest which is calculated to be 602rpm
c. Petrol engine selection: For constant supply of light, GX200 petrol engine with 6.5Hp for ultimate design and 5.5Hp for machine design was used.
d. Machine Torque: This was calculated to be 69KN.
e. Belt size: 12.5mm thickness of vee belt was used.
f. Size of shaft: 20mm diameter is passable from design the machine design but 28mm diameter is used for the ultimate design.
g. Tension in the V-belt: This was calculated to be 4.95KN on the tight side and 1.65KN on the slack side.
h. Speed of stirrer: This was calculated to be 6107rpm
i. The Speed Reduction of the gear pulley: This was calculated to be 1036rpm
j. Centrifugal Force Developed in the System: this was calculated to be 4.95KN

Material Consideration

Materials needed to fabricate this machine were selected based on:

i. Nigeria’s local content initiative policy.
ii. Availability of the material in the local markets

iii. Machinability
iv. Hygiene: Hygiene was less considered since the oil will undergo clarification and drying. The materials selected were majorly Mild steel except the pulleys that are aluminum.
v. Strength of the material and rigidity of the machine
vi. Durability
vii. corrosion under various uses and weather condition to which its exposed
viii. Economy / feasibility
ix. the cost of material and hence production cost with consumer in view

2.2 DESCRIPTION OF THE MACHINE

The machine consists of a frame, digesting chamber, hammers, petrol engine, vee belt, bevel gear and a stirrer. Boiled palm fruit was fed into the digesting chamber which is cylindrical in shape. In the digesting chamber, there is a stirrer having three hammers attached to it at 120˚to one another and will be separated by a distance of from one another. As the petrol engine start working, motion was transmitted to the stirrer by the bevel gear through the vee belt connected to the pulleys of the petrol engine and the gear. The perpendicular motion of the belts was transmitted into longitudinal motion of the stirrer.

3.3 DESCRIPTION OF COMPONENTS

The oil palm fruit digester consists of the following components; frame, hammers, stirrer shaft, hopper/digesting chamber, discharge chute, fibre and nut outlet, gear support frame, bevel gear, vee belt and pulley and petrol engine.

i. **Frame**: The frame usually provides rigid and skeletal support for the entire system. Apart from the four corner support of main frame work, it consists of two compartments, which were the support for the digesting chamber and another support for the petrol engine.

Figure 1.1: The frame

Hammers: The hammers were three in number. They hit the boiled palm fruit continuously depending on the speed of the stirrer.

Stirrer shaft: The stirrer shaft is a steel central shaft providing the size reduction effect on the oil palm fruits and is attached to the bevel gear drive.

Figure 1.2: Stirrer shaft with hammers

Hopper/Digesting chamber: The hopper is an opening on the digesting chamber. This unit Housed the stirrer shaft and hammers during operation. It is a cylindrical drum placed vertically with a top opening.

Figure 1.3: digesting chamber

Discharge chute: This is a continuation of the cylindrical flange at the bottom of the digesting chamber. It directs the flow of the crude palm oil to a receptacle.

Figure 1.4: discharge chute

Fibre and nut outlet: The fibre and nut outlet is a square opening on the side of the digesting chamber.

Bevel gear: It transmits power to the stirrer shaft at reduced speed and increased torque.

Figure1.5: bevel gear casing

Vee belt: The veebelt transmit power and motion from the petrol engine to the bevel gear via the pulley on the petrol engine and the bevel gear.

Petrol engine: petrol engine was used to power the machine and it was mounted on the frame by means of bolts and nuts.

Figure 1.6: Petrol Engine

PHYSICAL AND MECHANICAL PROPERTIES OF THE OIL PALM FRUIT

For a very effective design, the physical and mechanical properties of the oil palm fruits were determined.The physical properties are;

1. Size: To determine the size of the oil palm fruits, 10 fruits were selected randomly. The linear dimensions such as length, width and thickness were measured by a vernier caliper reading to 0.01mm. The measurement was repeated thrice for accuracy. The size was known to be 15mm by 13mm by 2.2mm.

2. Shape: The shape was expressed in terms of sphericity index and aspect ratio.

For sphericity index, the dimensions obtained for 10 palm fruits were used to compute the index based on the equation [19].

$Sc = \left[(abc)^{1/3}/a\right] \times 100$…………………1

Where a is the major diameter, b is the intermediate diameter, c is the minor diameter and Sc is the sphericity index.

For aspect ratio, the dimensions obtained for the 10 palm fruits wereused based on the equation [20].

$Ra = (b/a) \times 100$…………………………. 2

Where Ra is the aspect ratio, a is the major diameter and b is the intermediate diameter

3. Mass: This was determined by using a Mettler Toledo PB 153 electronic balance

4. True and bulk density: This was determined by water displacement technique [21]. The 10 fruits were weighed and put in a graduated cylinder containing a measured amount of water. The net volumetric water displacement of each fruit will be recorded. Therefore;

$\rho_t = m/v$…………………………………….3

where m is the mass of each fruit, v is the volume displaced by each fruit and ϱt is the true density

$\rho_b = M/V$……………………………….......4

where M is the total mass of the fruits, V is the total volume displaced by the fruits and ϱb is the bulk density.

5.Density ratio and porosity ratio: This was calculated using this formula

$Dr = (\rho_t / \rho_b) \times 100$…………………….5

Where Dr is the density ratio

$P = \{(\rho_t - \rho_b) / \rho_t\} \times 100$………………..6

Where P is the porosity ratio

The mechanical properties are;

1. Shear strength

According to [22],

Shear strength = applied shear force/fruit area……… 7

2. Hardness

$$Hardness = \frac{P}{\pi\frac{D}{2}\left(D-(D_2-D_1)^{\frac{1}{2}}\right)}$$ ………………………………… 8

Where P is the constant force, D is the brinnel bulb diameter and d is the depth of indentation

DESIGN CALCULATION

1. **Speed of the stirrer**

According to [23],

.$D_1N_1 = D_2N_2$ … … … … … … … … … … … … … … … Error! Bookmark not defined.

$N_2 = D_1N_1/D_2$………………………………….. 9

Where $D_1$the diameter of the engine pulley is, $D_2$is the diameter of the bevel gear pulley, N_1 is the speed of the engine, $N_2$is the speed transmitted to the stirrer

2. **Centrifugal force**

According to[17],

$Fc = Mw^2r$…………………………………………..10

$W = 2\pi N / 60$……………………………................ 11

$Fc = M(2\pi N / 60)^2 r$……………………............. 12

Where M is the mass of stirrer before attaching it to the bevel gear, r is the radius of the stirrer, w is the angular velocity of the stirrer shaft

3. **Torque developed**

According to [20],

$T = Fc \times r$………………………………………….. 13

Where Fc is the centrifugal force, r is the radius of the pulley on stirrer shaft

4. **Tension in the belt**

According to [24],

$(T_1/T_2) = 3$ (constant for Vee belt)…………………. 14

$T_1 = F_C$……………………………………......................... 15

$T_2 = F_C/3$……………………………………………...... 16

Where T_1 is the tension on the tight side of the belt and T_2 is the tension on the slack side of the belt.

2.4 PERFORMANCE TEST

Bulk sample of matured palm fruit were bought from the main market in Ekiti State. The fruits were inspected to check its quality. They were cleansed for dirt and other contaminant. The digester was assembled and the optimal speed was determined. Initial moisture content of the sample were collected. 8 samples of the palm fruit were boiled for 45minutes and poured into the digester and the time for each to digest was determined in rpm by stopwatch. Digestion rate and efficiency were determined using:

$D_C = (W/T_a) \times 60$……………………………… 17

Where D_C is the digestion rate, T_a is the average digestion time and W is the initial weight of palm fruit fed into the digester

$\eta = (W_d/W) \times 100$…………………………………. 18

where W_d is the weight of the digested fruit collected at outlet and W is the initial weight of the palm fruit fed into the digester fruit fed into the digester fruit fed into the digester.

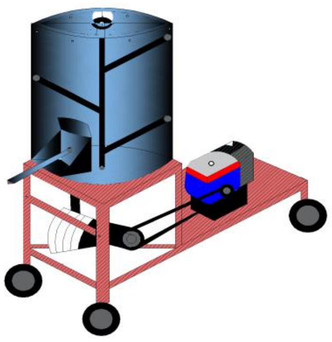
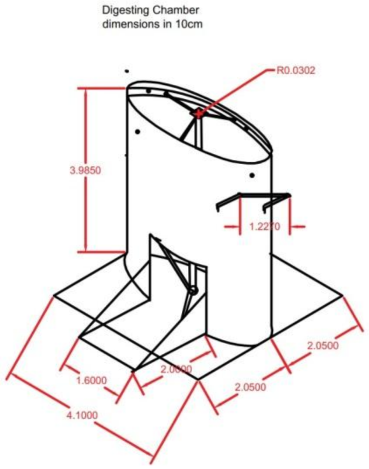


Figure III-3 Isometric view of the digester



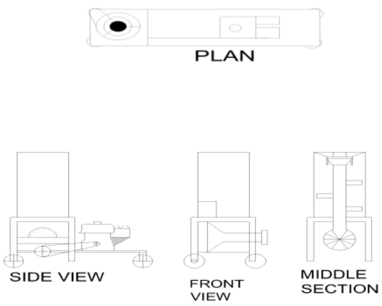
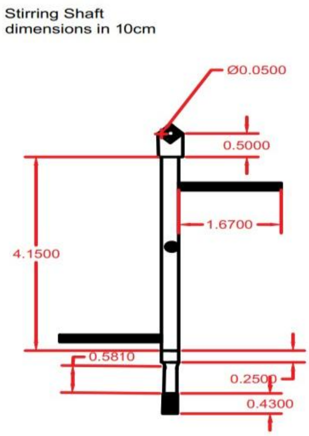
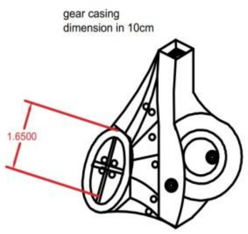
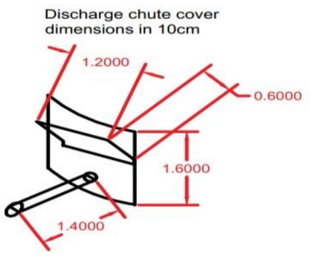


Figure III-4 Orthographic view of the digester







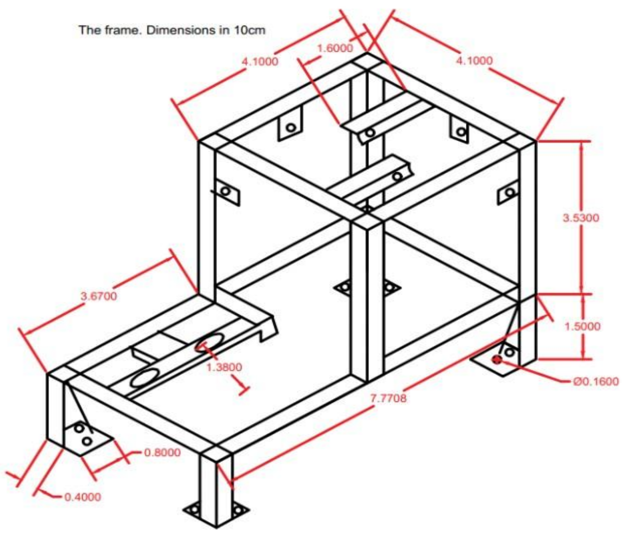


Figure 3-9: description of components

III. RESULTS

The improved palm oil digested was developed and tested. The different weights of unboiled fruits, boiled fruits, digested fruits and undigested fruits were noted. The boiling time and digestion time for each boiled fruit weight was also noted. Table 4.1 shows the experimental results showing the weight of boiled fruits in Kg, the weight of unboiled fruits in Kg, the weight of digested fruits in Kg, the weight of undigested fruits in Kg, boiling time in minutes and digestion time in minutes. Data from the experiment in the Table 4.1 shows that the test was performed twice for same weight of unboiled fruits to ensure accuracy and the variations in the weights of boiled fruits for same weight of unboiled fruits were analyzed. It can be seen from the table that there is increase in the weight of the fruits when boiled. This is due to increase in the moisture content of the fruits. This increase in weight varies for same weight of unboiled fruit. Therefore, to be accurate, the average weight for the boiled fruit was determined. The boiled fruits were digested.

Table 1: Showing the weight of boiled fruits, the weight of unboiled fruits, weight of digested fruits, the weight of undigested fruits , boiling time and digestion time.

	Weight of unboiled fruit (Kg)	Weight of boiled fruit (Kg)	Weight of digested fruit (Kg)	Weight of undigested fruit (Kg)	Boiling time (minutes)	Digestion time (minutes)
1	4	4.50	2.05	2.45	45	2
2	4	4.90	2.25	2.65	45	2
3	6	7.57	4.28	3.29	45	3
4	6	7.79	4.48	3.31	45	3
5	8	9.22	5.73	3.49	45	4
6	8	9.42	5.87	3.55	45	4
7	10	12.00	7.02	4.98	45	6
8	10	11.80	7.26	4.54	45	6

From the Table 1, it can be seen that some of the fruits were digested and some were not digested. Percentage gain and loss was calculated for each weight of digested and undigested fruits respectively. The weights of the digested fruits varies. It increases gradually with increase in the weights of the boiled fruits. Theweights of the undigested fruits also varies. It increases with increase in the weights of boiled fruits. The undigested fruits consists of the nuts and fibres. The percentage gain of the digested fruits correspond to the machine efficiency. The boiling time of the fruits was said to be constant throughout the experiment in order to ensure same heat gain for the different weights of fruits being boiled. It can also be seen that the digestion time varies as the weight of fruits increases. Table 4.1 shows that increase in the mass of palm fruits increases the digestion time and digesting capacity of the digester. Table 2 shows the weights of digested and undigested fruits and the percentage gain and loss based on the boiled fruit weight. It can be seen that the percentage gain increases at the beginning and later start decreasing and percentage loss of palm fruits decreases at the
beginning and later increase. This means that the machine perform more efficiently at the highest percentage gain of digested palm fruits.

Table 2 : Weights of digested and undigested fruits and the percentage gain and loss based on the boiled fruit weight

	Weight of unboiled fruit (Kg)	Weight of boiled fruit (Kg)	Weight of digested fruit (Kg)	Weight of undigested fruit (Kg)	Percentage gain (%)	Percentage loss (%)
1	4	4.50	2.05	2.45	45.55	54.44
2	4	4.90	2.25	2.65	45.92	54.08
3	6	7.57	4.28	3.29	56.54	43.46
4	6	7.79	4.48	3.31	57.51	42.49
5	8	9.22	5.73	3.49	62.13	37.87
6	8	9.42	5.87	3.55	62.33	37.67
7	10	12.00	7.02	4.98	58.50	41.50
8	10	11.80	7.26	4.54	61.50	38.50

The table 3 describes the average weights of the boiled fruits, digested fruits and undigested fruits, average digestion time and the average percentage gain and loss of the boiled fruits. The average weights of boiled fruits increases, likewise the average weights of digested and undigested fruits increases. The average digestion time increases with increase in digested fruits weight. The average percentage gain and loss doesn't follow the same trend. There is a gradual increase in percentage gain at the beginning and a gradual fall at the end. There is a gradual decrease in percentage loss at the beginning and a gradual rise at the end. This means that percentage gain and loss are inversely proportional to each other.

Table 3: The average weights of the boiled fruits, digested fruits and undigested fruits, average digestion time and the average percentage gain and loss of the boiled fruits.

	Average weight of boiled fruit (Kg)	Average weight of digested fruit (Kg)	Average weight of undigested fruit (Kg)	Average Digestion time (hours)	Average percentage loss (%)	Average percentage gain (%)
1	4.70	2.15	2.55	0.033	54.26	45.74
2	7.68	4.38	3.30	0.050	42.97	57.03
3	9.32	5.80	3.52	0.067	37.77	62.23
4	11.90	7.14	4.76	0.083	40.00	60.00

The digester performance result presented in Table 4 shows the average throughput capacity, Dr and efficiency, η. The digestion rate increases from weight 1 to weight 2 and weight 2 to weight 3 and later decreases from weight 3 to weight 4. The digestion rate follows same trend as the efficiency. This means that the digestion rate and efficiency are directly proportional to each other. The digestion rate has its peak at weight 2 which is 153.6Kg/hr. the optimal efficiency occurs at state 3 which is 62.23%. this point shows that the machine is efficiently and effectively set for use.

Table 4: the average throughput capacity, Dr and efficiency, η.

	Average weight of boiled fruit (Kg)	Average weight of digested fruit (Kg)	Average weight of undigested fruit (Kg)	Digestion time (hours)	Digestion rate (Kg/hr)	Efficiency (%)
1	4.70	2.15	2.55	0.033	142.424	45.74
2	7.68	4.38	3.30	0.050	153.600	57.03
3	9.32	5.80	3.52	0.067	139.100	62.23
4	11.90	7.14	4.76	0.083	143.37	60.00

The average digestion rate and efficiency are 144.624Kg/hr and 56.25% respectively. The highest capacity was 153.6Kg/hr and was obtained with an initial mass of 6Kg and the highest efficiency was 62.23% and was obtained with an initial mass of 8Kg. The digester capacity could be increased for large scale digestion of palm fruits.In addition, the efficiency of the palm fruit digester increased with increase in the mass of palm fruits from 4Kg to 6Kg and from 6Kg to 8Kg while the efficiency of the palm fruit digester start decreasing from 8Kg to 10Kg with increase with the digestion time. This simply means that the accurate digestion time is being taken for the 6Kg palm fruit mass which is 0.05hr. In most cases, there is significant increase in the efficiency of the oil palm fruit digester while in some cases, the efficiency of the palm fruit digester increases with increase in the mass of palm fruit.The average efficiency of 56.25% conform to standard when compared to standard in table 2.5 which is 55% for a motorized horizontal digester.The Table 5 shows that the speed increases as the digestion time decreases. The optimal speed of the digester is 602rpm by taking the average speed. The developed palm oil digester was found to perform satisfactorily with all the mass of the fresh palm fruit poured into it at constant operational speed of 602rpm when tested.

Table 5: Average weight of palm fruits and the digester speed.

	Average Weight of palm fruit (Kg)	Speed of digester (rpm)
1	2	600
2	4	601.5
3	6	602.5
4	8	604

Table 6: Average boiling time in hours and average weight of boiled palm fruits

	Average weight of boiled fruit (Kg)	Boiling time (hours)
1	4.70	0.75
2	7.68	0.75
3	9.32	0.75
4	11.90	0.75

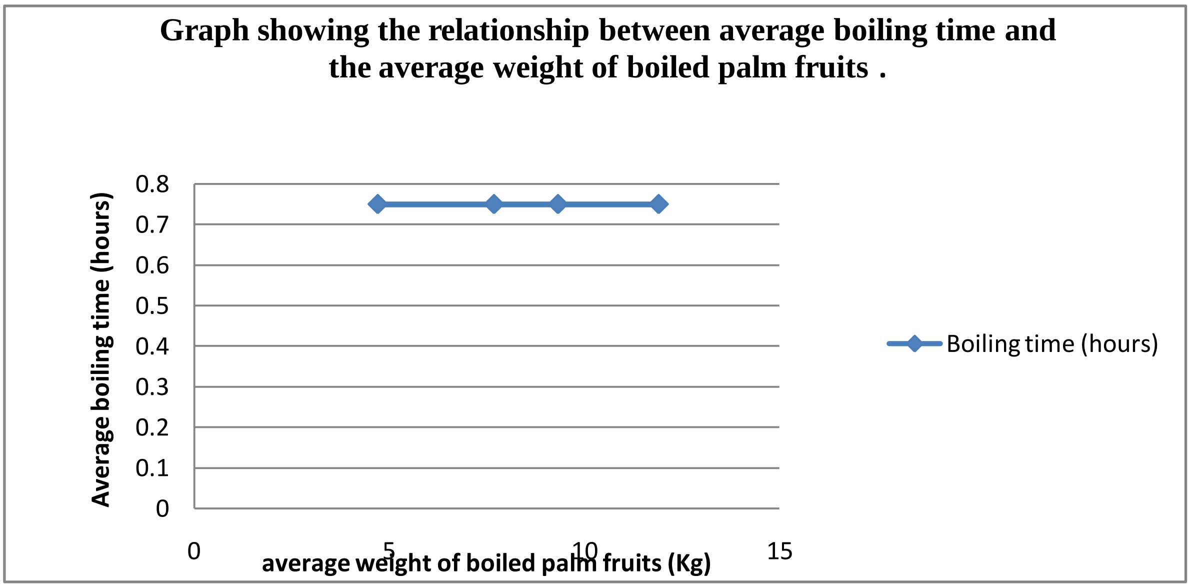


Figure 1: Graph of speed of digester against average weight of palm fruits

From the Figure 1, it can be seen that the improved palm oil digester operate at almost same speed. The speed hovers around 600rpm in which the average speed is 602rpm. This simply means that the machine settings is correct and the digested fruit being turned by the stirrer are not too large.

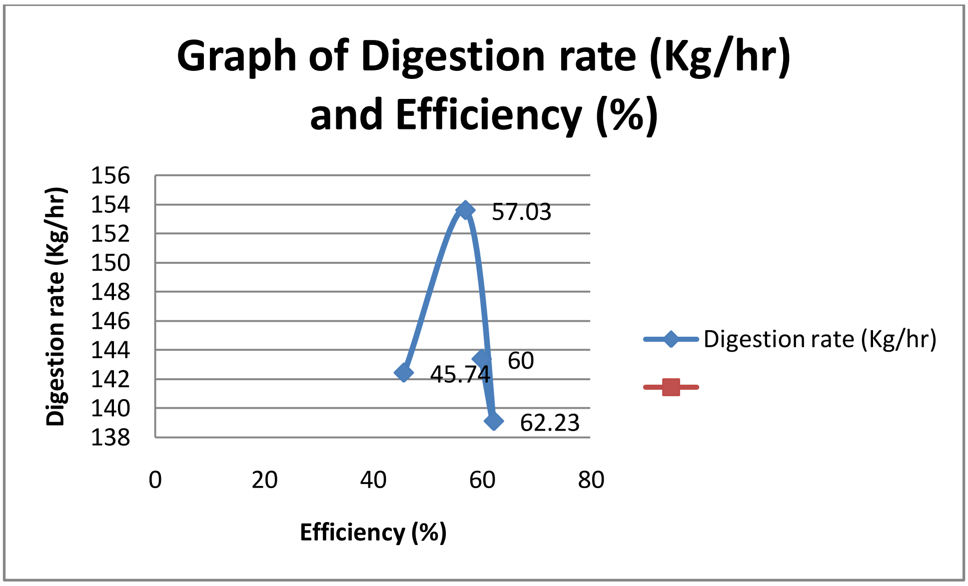


Figure 2: Graph of efficiency against digestion rate

From the Fig.2, it can be seen that the digestion rate is at its peak at about 143kg/hr. before it starts reducing gradually. This means that the experimental condition is best at the average weight of 6kg because the weight of digested fruit at the digestion time produces the maximum efficiency.

IV. CONCLUSION

The machine has an optimal efficiency of 62.23% and discharge capacity of 153.6Kg/hr. Also, its easy to operate and maintain and it is mobile. The test and performance evaluation shows that the machine can be used by farm cooperatives and women in rural communities. Therefore, manufacturers should take up this innovation and implement it in the mass processing of red oil palm fruit for export, domestic and industrial uses.The digester machine that contained the improved features in the area of lubrication system in which thick oil called axle oil will be used and the gear teeth is closed. There is adjustable screw tensioning at the belt and the machine is detachable and moveable and it can perform optimally with high digestion rate and efficiency.

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