American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-8, Issue-12, pp-195-205
www.ajer.org
Research Paper Open Access

Design and Fabrication of a Motorized Oil Palm Fruit Rotary Digester Machine

I.S. Oghenevwaire[1], D.U., Owuamanam[2], I.S., Anisha[3]
[1]Department of Mechanical Engineering, Federal University of Petroleum Resources, Effurun, Nigeria
[2]Department of Production Engineering, University of Benin, Benin City, Nigeria
[3]Department of Welding Engineering and Offshore Technology, Petroleum Training Institute, Effurun, Nigeria
Corresponding author; Oghenevwaire Iyabo Seyefa; iyabocoker40@gmail.com

ABSTRACT :*Palm oil is the world's largest source of edible oil, accounting for 38.5 million tones or 25% of the global edible oil and fat production. Palm oil has been an important ingredient in the diet of many Nigerians.It is estimated that for every Nigerian household of five, about two liters of palm oil are consumed weekly for cooking. Despite the high consumption of the product by average Nigerians, existing technology of processing the product locally are associated with problems such as; unhygienic production processes, high rate of human energy consumption, time-consuming and drudgery etc., thus this research work. The vertical digester machine designed consists of a cylindrical vessel (drum) that is fitted to a central rotating shaft carrying a number of beater arms, feed hopper which serves as the intake chute for the parboiled palm fruit, digester barrel, bearings, main shaft, beater arms, discharge end, electric motor, frame, etc. It works on the rotary impact principle. The digester barrel carries the hopper and the shaft assembly which lies in the central position of the barrel. The shaft assembly is made up of six beater arms which are arranged specifically at angles and distances strongly welded to the shaft in the horizontal position. When connected to a reliable source of power, the electric motor shaft is set in motion at a fixed speed of 1800rpm which is connected to the beater shaft by a welded joint. This sets the digestion process in motion.The total weight of the palm fruit was approximately 12kg and was split into three parts of 4kg each. The boiled palm fruits are macerated for some time and then the discharge chute is opened for the products to come out for pressing.The vertical palm fruit digester was designed, fabricated and performance evaluation carried out. The results of detailed design of the fabricated motorized oil palm fruit rotary digester machine showed that a rupture force and power of 275.37 N and 2.5hp were required. The results of the performance test show that the machine is efficient (70.8%). With an average machine throughput capacity of 0.030kg/sec, the machine performance is satisfactory.*

KEYWORDS: *Palm oil fruit,design, fabrication, vertical motorized oil digester, efficiency*

Date of Submission: 20-12-2019 Date of acceptance: 31-12-2019

I. INTRODUCTION

The global demand for palm oil is on the increase. The cultivation of the crop serves as a means of livelihood for many rural families, and indeed it is in the farming culture of millions of people in Nigeria.Palm kernel oil is an important commodity in Nigerian economy with reference to its role as a source of farm income and food requirement. Besides, it provide direct and indirect employment for about four (4) million people, and also contributes around 70% of the country's national consumption requirement of vegetable oils [1-2]. The crop is often referred to as a crop of multiple values, which underscores its economic importance. The demand for domestic and industrial application of palm oil has continued to increase. It is estimated that for every Nigerian household of five, about two liters of palm oil are consumed weekly for cooking [3]. Nevertheless, palm oil a product extract of palm fruit is an essential multipurpose raw material for both food and non-food industries. Palm oil is used in the manufacturing of margarine, soap, candle, base for lipstick, waxes and polish bases in a condense form, confectionary, pharmaceuticals, tin plating, lubricant, biodiesel, fat spread, ice cream, coffee whiteners, whipping creams, fatty acids free formulation, palm-based cheese, micro-encapsulated, filled milk, mayonnaise and sealed dressings, red oil/olefin [4]. Also, with the growing population of Nigeria, an increase in the number of families, and communities, there will be an increase demand and compensating consumption rate in the country for oil palm products, most especially the red oil for daily cooking and consumption. Thus, a local technology that can be used to process the fruit will be paramount. Such technology will help to reduce the rate at which local and industrial batch users will use in handling the material (drudgery) for palm oil processing. It will also help to achieve increase in productivity as the time and energy it will take for palm oilto be locally processed can be reduce twice the rate using mechanical means. Therefore, this research work is of utmost importance because further development could be carried out on it as it would serve as a foundation for further study on the subject matter.

Besides, any delay in the processing of fruits can lead to increase in free fatty acid (FFA) content of palm oil and this causes a drop in quality [5]. Also, the existing local technology of digestion that had been used over the year by average Nigerians is very laborious, tedious and time-consuming process. It is done in rural areas where there are no mechanized and easy ways of producing palm oil. The palm bunches are quartered manually with a sharp cutlass and left overnight for easy separation of nuts from the spikelet. The fruits are boiled for 1.0 to 1.5 hours in a drum with water heated bylocal firewood, pounded in a mortar or macerated with feet in a canoe-like container. Water is added and well-shoveled up [6-7].

Digestion is the process of releasing the palm oil in the fruit through the rupture or breaking down of the oil-bearing cells. The digester machine commonly used consists of a cylindrical vessel fitted with a central rotating shaft carrying a number of beater (stirring) arms. Through the action of the rotating beater arms by a prime mover, usually a fuel, diesel engine or an electric motor, the fruit is pounded [7]. However, most small scale digesters do not have the heat insulation and steam injections that help to maintain their contents at elevated temperatures during this operation for reasons related to cost and maintenance. Moreover, contamination from iron is greatest during digestion when the highest rate of metal wear is encountered in the production process. Iron contamination increases the risk of oil oxidation and the beginning of oil rancidity; thus the material is carefully selected and prepared for such application.Digesters come in two major categories and these are vertical digester and horizontal digesters.

The vertical digester consist of the hopper, digester barrel, sealed bearings, main shaft, beaters arms, discharge end, worm gear, wheel gear and the prime mover. The vertical digester's barrel carries the hopper and the shaft assembly which lies in the central position of the barrel. On entry through the hopper the parboiled oil palm fruits, the vertical digester macerate the fruits for some minutes and automatically discharge the macerate through the exit end by gravity. The power or motion is supplied by either a petrol engine or by an electric motor. The use of gears also helps to regulate the power transmitted and improves the efficiency of the machine. More so, in the horizontal digester, digestion is done by the beater arms which also convey the macerated oil palm fruits from the digester posterior end to the exterior end automatically due to the conveyor – screw – arrangement of the beater arms [8]. The horizontal digester has been tested on several occasions and it has been established to have a thorough maceration (digestion), smooth and continuous discharging, Easy to maintain and operate, ability to break up all the oil bearing cells, ability to digest without cracking or breaking the nuts, portability and very high efficiency [8]. Besides, this concept is usually accompanied by low belt drive efficiency due to slippage and improper design of the pulley system and whirling of the digester main shaft due to increase in length [9].

II. MATERIALS AND METHODS

2.1 Materials

The material selection for this research work is based on service requirement, fabrication requirement, and economic requirement as reported by [10]. The Service requirement involves the properties a material should have, to serve the purpose for which it is designed for and some of these properties include: corrosion resistance, strength, toughness, resistance to heat, maintainability, safety, etc.[10].Fabrication requirement necessitates workable properties a material should have, and they include machinability, forgability, malleability, ductility, weldability, castability, etc. The economic requirement entails the affordability of the material for fabrication and commercialization of the product[11].Table 1 shows the summary of choice of materials used in this research work.

Table 1. Summary of the choice of materials selected

Part	Choice of materials	Justification
Power source	Electric motor (wound-rotor induction motor)	• Low cost, robust and reliable • It is portable and easily applied • Self-starting • Fixed speed • Less power consumption • Low vibration and noise.
Square pipe and flat bar	Mild steel	• It can be easily machined • It can be easily acquired from the local market • It is affordable

		• Ease of fabrication in local workshops
Digester Barrel/Drum	Mild steel	• It is cheaper and readily available • Ease of fabrication • High resistance to deformation
Main shaft	Mild steel	• It can be easily machined • It is cheaper and readily available • Harden ability
Bearing bearing	High Carbon Steel	• Resistance to wear and corrosion, hard, tough and has high strength.
Frame stand	Mild steel	• For strength, toughness, withstand shear force and compressive

2.2 Methods
The following methods were adopted in this research work.

2.2.1 Design Considerations
The following factors were considered while designing the machine;
i. The environment
ii. Load capacity
iii. Material properties
iv. Reliability of the system
v. Maintenance strategy

2.2.2 Design Alternatives
Table 2 depicts different design alternative that could be selected for this research work.

Table 2. Design Alternatives

Consideration	Design alternatives				Selection
	A	B	C	D	
Prime mover	Petrol engine	Diesel engine	Electric motor	Steam engine	C
Frame stand	Pipes	Angle bar	Flat bar	Wood	B & C
Drum	Stainless steel	Mild steel	Iron	Aluminum	B
Shaft	Steel	Aluminum	Iron	Wood	C

Thus, an electric motor, angle bar, flat bar, mild steel, and Iron were selected.

2.2.3 Design Determination
According to [12], having considered the primitive method of digestion and mechanized rotary action of the oil palm fruit digester, a lot was taken to determine the development of the machine.

- Higher capacity compared to the traditional/primitive method of the palm fruit digestion.
- Reduction in drudgery associated with the traditional/primitive method.
- Strength of material should withstand the force acting on the various components of the rotary palm fruit digester.
- Simplicity and complexity of the digester should suit the intended user(s) and has no side effect on him and his environment.
- The angle of inclination of the hoer was 45^0 to the horizontal.
- The general configuration of the machine and the factors of safety administered for effectiveness and efficiency.
- The power ratings of the electric motor to be used.
- The configuration and operation techniques of the machine when in operation.
- Ease of operation, choice of material and machine affordability.

2.2.4 Design Requirement
The following functional parameters and component parts are required in this research work:

- High strength (tensile and compressive) material
- Density and weight of boiled palm nuts.
- Power required: Low speed industrial electric motor
- Main shaft diameter
- Digester arm diameter

- Selection of bearing for shaft

2.2.5 Design Consideration
- Volume of the drum
- Full load condition
- Power determination
- Machine Torque
- Electric motor
- Shaft diameter
- Bearing selection

2.2.6DetailedDesign
a. Volume of the Drum
The volume of the drum is given by Equation (1).

$$V=\pi r^2 h \quad (1)$$

where,
h= Height of drum
r= Internal radius of the drum
d_i= Internal diameter=409.09mm,
$r_i = \frac{409.09}{2}$ =204.55mm
d_e= external diameter= 413.13mm
h= 411.15mm
$V=3.142\times 204.55^2\times 411.15 = 54065.95mm^3 = 0.05m^3$

b. Required Load
The density of boiled palm fruit is given by Equation (2).

$$\rho=\frac{m}{v} \quad (2)$$

where,
m= mass of boiled fruit
v= volume of the drum
$\rho = \frac{12}{54065.95} = 0.000221kg/m^3$

c. Power Determination
In accordance with the American society of Agricultural Engineers (ASAE), the rupture strength of palm fruit sterilized at 100°C under atmospheric pressure for a period of 45 minutes is $1.082N/mm^2$ [13].Using the above value, the rupture force can be determined as follows;

$$S_R = \frac{F_R}{A_M} \quad (3)$$

where,
S_R = rupture strength
A_M = area of palm fruit mesocarp (mm^2)
F_R = rupture force (N)
Assuming that the palm fruit is a sphere, the area can be determined as follows;

$$A_M = 4\pi (R_m)2 \quad (4)$$

d. Machine Torque
Torque transmitted per digester arm is given by Equation (5).

$$(T_d) = F_R x L_D \quad (5)$$

where,
L_D = Length of digester arm
Thus, total torque in the digester

$$(T) = Td \times n \quad (6)$$

where,
n = Number of digester arm
$F_R = m\omega 2Ld$
The angular speed of shaft (ω) is determined from Equation (7)

$$\omega = \sqrt{\frac{F_R}{mL_D}} \quad (7)$$

$F_R = mg$

$m = \frac{F_R}{g}$

Therefore,

$$\omega = \sqrt{\frac{g}{L_D}}$$

$$P_d = T\omega \quad (8)$$

where,

P_d =Power required of the digester

T = Torque

ω = Angular velocity

The area of palm fruit mesocarp (mm^2)

$A_M = 254.5mm2$

The rupture force is calculated as shown;

F_R= 1.082 x 254.5

$F_R = 275.37N$

Torque transmitted per digester arm (T_d) = $F_R x L_D$

T_d = 275.37 x 0.127 = 34.9Nm

Total torque in the digester $(T) = Td \times n = 34.9 \text{ x } 6 = 209.4Nm$

$F_R = m\omega 2Ld$

$$\omega = \sqrt{\frac{10}{0.127}}$$

ω = 8.9rad/sec

$P_d = T\omega$

P_d = 209.4 x 8.9

P_d = 1863.6w

$P_d = \frac{1863.6w}{746w} = 2.49hp \approx 2.5hp =$

e. Shaft Diameter

For solid shaft, which are subjected to bending and torsion, the diameter (d) is obtained from;

$$\tau_s = \frac{16}{\pi d^3}\sqrt{(K_b M_b)^2 + (K_t M_t)^2} \quad (9)$$

Therefore,

$$d^3 = \frac{16}{\pi \tau_s}\sqrt{(K_b M_b)^2 + (K_t M_t)^2} \quad (10)$$

According to ASME,

τ_s = maximum allowable shear stress =$0.3\sigma_{yt}$ without keyways

K_b = combined shock and fatigue factor applied to bending moment= 1.5

K_t= combined shock and fatigue factor applied to torsional moment=1.0

M_b = bending moment

M_t = torsional moment

For this digester, the beater arms are mainly subjected to bending moment. Therefore Equation (10) becomes,

$$d^3 = \frac{16}{\pi S_s}\sqrt{(K_b M_b)^2} \quad (11)$$

The bending moment on the digester arm is determined as follow;

M_b = FR xL_d

M_b = 275.37 x0.127= 34.96Nm

For this digester, the beater arms are mainly subjected to bending moment.

$$d^3 = \frac{16}{\pi S_s}\sqrt{(K_b M_b)^2}$$

$$d^3 = \frac{16}{3.142 \times 0.3}\sqrt{(1.5 \times 34.96)^2} = 1.52\sqrt{2747.95} \quad = 79.65$$

$$d = \sqrt[3]{79.65} = 27mm$$

f. Bearing Selection

The bearing rating life according to the American bearing manufacturer association (ABMA) and the International organization for standardization (ISO) is given as;

$$L_{10} = {}^{C}/_{P} \times 10^{6} \tag{12}$$

where,
C= dynamic capacity (N)
P= equivalent bearing load
N= rotating speed(rpm).
e=0.3 for ball bearing

2.2.7Description of the Oil Palm Fruit Digester

The machine is made up of the following major components; electric motor, digester barrel/drum, main shaft , beater arms, discharge end, frame stand , ball bearings, and bolt and nuts

a. Electric Motor

The electric motor is the prime mover present in the machine. It is powered by an electric output source which then drives the main shaft connected to it. It helps in reducing the noise, vibration and stress other prime movers might induce in the system.In this research work, three-phase squirrel-cage induction motors were used. Three-phase squirrel-cage induction motors are widely used as industrial drives because they are self-starting, reliable and economical.

b. Digester Barrel/Drum

The digester barrel is the part that houses the main shaft which carries the beater arm; the electric motor is mounted on the digester drum when in operation. Parboiled oil palm fruits are fed into the digester barrel through the feed hopper. The electric motor serves as the prime mover which powers the shaft and beater arms for turning or digesting. It is a simple 15x15 inch cylindrical drum shape and it is placed vertically with a hopper on the barrel cover at the top. The bottom part of the digester barrel has a discharge end with a dimensioned of 4x4inch.

c. Main Shaft

The main shaft is made from amild steel rod with a dimension of 27mm diameter and height of 19inch. The beater arms are attached at its sections (5inch), centrally located in the digesting barrel and is supported at both ends by a sealed ball bearing.

d. Frame Stand

The frame stand is a base which provides rigid and skeletal support of length 17inch x 25.5inch for the entire machine system (Fig.1). It consists of compartments for both the digesting chamber and the prime mover (electric motor). The frame is made of mild steel angle bar (45^{o}, 1.5 x 1.5 inch, 4mm thick) which is joined by welding to provide a very rigid joint. The frame is attached to the digesting barrel by bolts and knots.

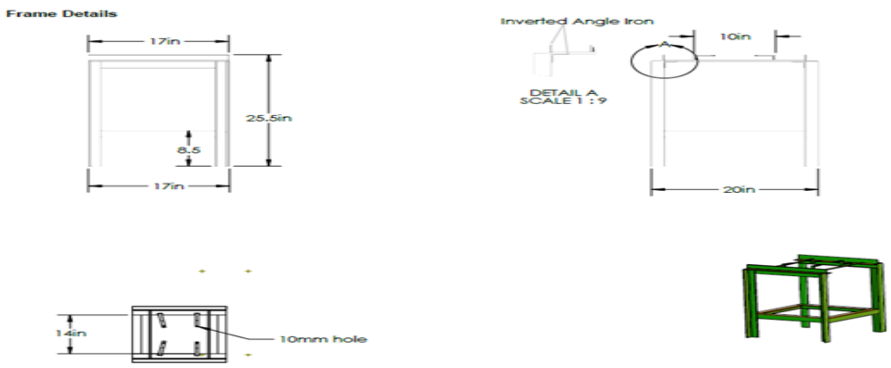


Fig. 1 Frame stand

e. Beater Arms

The beater arms as shown in Fig. 2are elements which are attached horizontally to the main shaft.

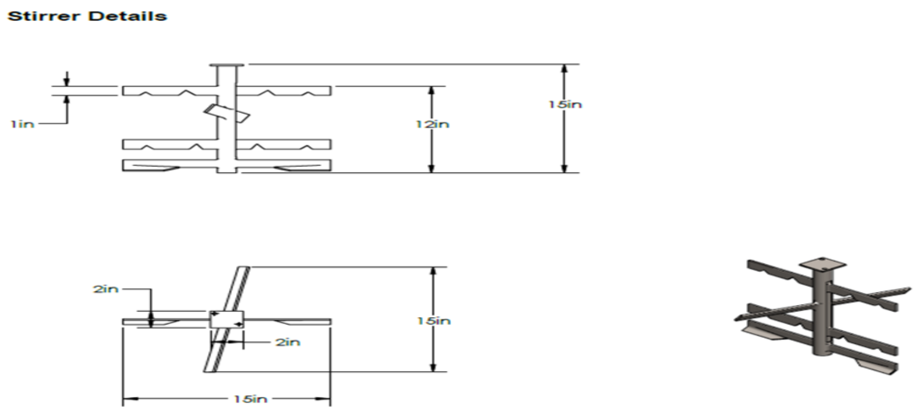


Fig. 2 Beater arms

The isometric modeled view of the machine is shown in Fig. 3

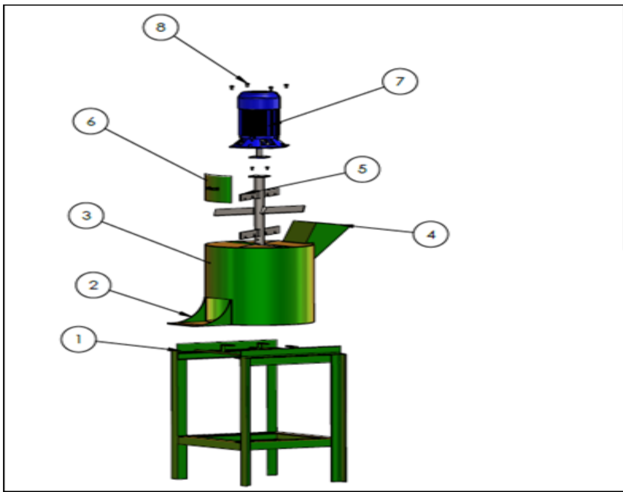
Fig. 3 Isometric modeled viewof the motorized oil palm fruit rotary digester machine

f. Discharge End

The discharge end is located at the bottom end of the digester barrel. It is the opening (4x4 inch) through which the macerated oil palm fruit is directed from the digester barrel to a receptacle.

g. Bearings

Ball bearings are used in this machine. They are located at both ends of the main shaft in order to reduce friction between the contacting parts and increase shaft speed.The exploded view of the of the motorized oil palm fruit rotary digester machine is shown in Fig. 4.



ITEM NO.	PART NUMBER	QTY.
1	Frame	1
2	Discharge Outlet	1
3	Digester Compartment	1
4	Hopper	1
5	Stirrer	1
6	Discharge Cover	1
7	Electric Motor	1
8	B18.2.3.2M - Formed hex screw, M6 x 1.0 x 10 --10WN	6
9	Bearing	1

Fig. 4 Exploded view of a motorized oil palm fruit rotary digester machine

The sectional view of the motorized oil palm fruit rotary digester machine is shown in Fig. 5.

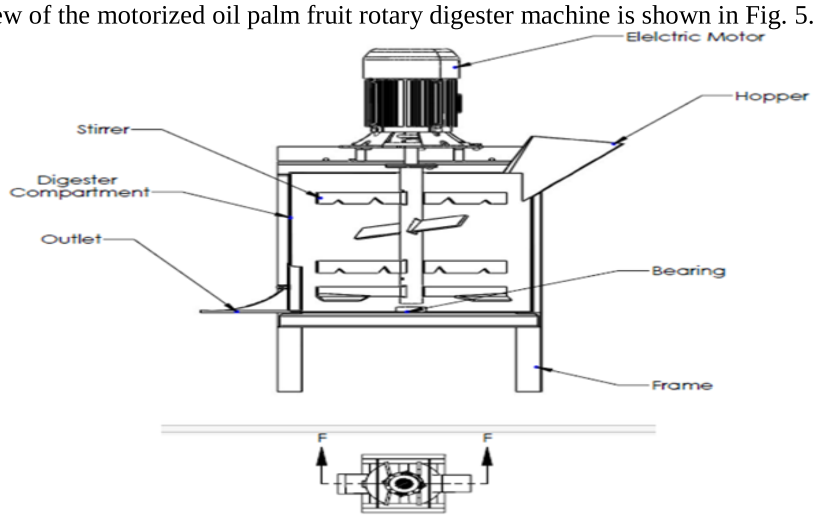


Fig. 5 Sectional view of the motorized oil palm fruit rotary digester machine

2.2.8 Fabrication Process

The fabrication process involves using the selected materials and constructing the product based on the design and the desired dimension. The various methods used during the fabrication of the machine from start to finish include; measuring, marking, cutting, joining, drilling and finishing. This was done part by part before assembly of each component.

•**Measurement:**Materials were measured according to the desired dimensions of the design.
•Marking: All measured materials were marked in the main sheet or full material to give precise dimension before cutting.
•**Cutting:**Marked materials are then cut into pieces.
•**Joining:** Materials were joined together by the arc welding for permanent joint and temporary joint by riveting.
•**Drilling:** Marked holes are then drilled to make holes for bolts.
•**Finishing:** Any rough surface or sharp edge was grinded to give smooth and safe surface. Plate 1 shows the fabrication phase.

Plate 1. Fabrication phase

Plate 2 shows the fabricated machine.

Plate 2. Fabricated motorized oil palm fruit rotary digester machine

2.2.9 Working Principle of the Machine

The vertical digester machine designed consists of a cylindrical vessel (drum) that is fitted to a central rotating shaft carrying a number of beater arms, feed hopper which serves as the intake chute for the parboiled palm fruit. With the aid of the rotating beater arms by a prime mover (electric motor, the fruit is being digested. The vertical motorized oil digester works on the rotary impact principle. It consists of the hopper, digester barrel, bearings, main shaft, beater arms, discharge end, 2hp electric motor and the frame. The digester barrel carries the hopper and the shaft assembly which lies in the central position of the barrel. The shaft assembly is made up of six beater arms which are arranged specifically at angles and distances strongly welded to the shaft in the horizontal position. When connected to a reliable source of power, the electric motor shaft is set in motion at a fixed speed of 1800rpm which is connected to the beater shaft by a welded joint. This sets the digestion process in motion. The boiled palm fruits are macerated for some time and then the discharge chute is opened for the products to come out for pressing.

III. RESULTS AND DISCUSSION

The palm fruit of about 9kg was sourced from a local market in Effurun, Delta State, Nigeria. The fruits were washed and cleansed for dirt and other impurities before being boiled for approximately 120 seconds using a gas cooker and a stop watch to accurately measure the time. The mass of the palm fruit after boiling was weighed to be 12kg. After proper assembly and installation of the digester machine, the digestion chamber of the machine was carefully inspected, washed and cleaned to prevent any health hazards.The palm fruits were weighed using a spring mass weighing scale. The total weight was approximately 12kg and was split into three parts of 4kg each. Table 3 shows the various mass of boiled palm fruits.

Table 3. Various masses of boiled palm fruits

Test	Mass of boiled palm fruits (kg)	Time taken (s)
1	4	120
2	4	130
3	4	150
∑	12	400
Average	4	133.33

3.1 Mass Output

Mass of boiled palm fruit (input) = 12kg
Mass of palm fruit not properly mashed = 3.49kg

The mass output was obtained as the difference between boiled palm fruit and mass of un-macerated palm fruit.

The mass output = Mass of boiled palm fruit – Mass of un-maceratedpalm fruit= 12 – 3.49 = 8.51kg

It is observed that the time taken for each mass of palm fruit to be digested increases except the first mass. This was due to the fact that not all the palm fruit are been digested. Thus, when it is discharge, the un-macerated ones are been separated and poured back into the drum. This test is been repeated twicewhile the time increases as the palm fruit increases inside the drum. Also, the un-macerated fruit is known as the ERROR test and it is being subtracted from the total mass of boiled fruit to give the output.

3.2 Efficiency of the Machine

From the three tests carried out. A total mass of 12kg of boiled palm fruits was taken, split into 3 sections of 4kg each and fed through the hopper when the machine was in operation. The mass of palmfruits not properly macerated was separated and weighed to be 3.49kg.

The efficiency is thus calculated as follows;

Efficiency = (Output/Input) × 100%= (8.5/12) × 100%= 70. 8%

Thus, the machine is 70.8% efficiency. The machine through-put capacity is calculated from Equation (13)[14].

$$\mathrm{MTC} = \frac{\mathrm{M}}{\mathrm{T}} \quad (13)$$

Where,

MTC = Machine throughput capacity

M = Mass of processed of palm fruit

T = Processing time

Thus,

$$\mathrm{MTC} = \frac{4}{133.33} = 0.030\mathrm{kg/sec}$$

With an average machine throughput capacity of 0.030kg/sec, the machine performance is satisfactory.

Table 4 shows the results of detailed design of the fabricated motorized oil palm fruit rotary digester machine. The rupture force was calculated as 275.37 N. Power required of the digester were determined by the expression which states that the power is the product of torque (T) and angular velocity (ω). A 2.5hp electric motor with a motor speed of 1,800rpm was selected to give the required torque in the digester.Torque transmitted per digester arm and total torques in the digester was obtained as of 34.9 Nm and 209.4Nm respectively. The volume of the drum was obtained as $0.05m^3$.

Table 4. Results of detailed design

S/N	Parameters	Determined Value	Unit
1.	Volume of the drum	0.05	m^3
2.	Density of boiled palm fruit	0.000221	kg/m^3
3.	The area of palm fruit mesocarp	254.5	mm^2
4.	Rupture force	275.37	N
5.	Torque transmitted per digester arm	34.9	Nm
6.	Total torque in the digester	209.4	Nm
7.	Required power	2.5	hp
8.	Bending moment on the digester arm	34.96	Nm
9.	Main shaft diameter	27	mm

IV. CONCLUSION

A vertical palm fruit digester was designed, fabricated and performance evaluation carried out. The test result revealed that the machine has an efficiency of 70.8%. The machine is made up of simple components that can be easily assembled. It is designed so that local users can easily carry out maintenance and at the same time operate the machine with ease for palm oil production.

V. RECOMMENDATIONS

From careful observation of the performance of this machine, it is important to proffer some recommendations based on the observations from the operation of the machine;

i. There is need for the inclusion of dampers in the digester to reduce problems associated with vibrations of the machine when in operation.

ii. The use of electric powered motor engine to eliminate dependency on petrol and flaring of harmful exhaust gasses into the atmosphere is of utmost importance.

iii. Since the efficiency is above average, thus, the vertical digester machine is highly recommended for end users in palm oil processing.

REFERENCES

[1]. Oyejide, O.J., Omeche Vitalis-Mary, M., Elkanah S.B., Adeleke, T.B. Design and Construction of a Palm Kernel Oil Extraction Machine. Design and Construction of a Palm Kernel Oil Extraction Machine.Nigerian Journal of Engineering Science Research (NIJESR). 1(1): 22-29 (2018).

[2]. Nzeka, U.M. Nigeria Provides Export Market for Oilseeds and Products. GAIN Report, USDA Foreign Agricultural Service (2014)

[3]. Elijah I. O, Cletus I. E, Sylvester C. I, Dorcas A. E. Small-Scale Palm Oil Processing Business in Nigeria; A Feasibility Study Greener Journal of Business and Management Studies 4(3); 070-082 (2014)
[4]. Olayiwola, S.T. Design and construction of palm nut cracker. Nigeria Journal of Palm and Oil Seeds. 9(1): 1819 (1988)
[5]. Adebayo, A.A. Development and Performance Evaluation of a Motorized Palm Nut Cracking Machine. Proceeding of the Annual Conference of the Nigerian Institution of Agricultural Engineers. 26: 326-330 (2004)
[6]. Aghalino, S.O. British Colonial Policies and the Oil Palm Industry in the Niger Delta Region of Nigeria, 1900-1960. African Study Monographs 21(1): 19-33 (2000)
[7]. Akangbe, J.A., Adesiji, G.B., Fakayode, S.B. and Aderibigbe, Y.O. Characteristics of Small-Scale Palm Oil Production Enterprise in Anambra State Journal of Human Ecology, 33(2):139-145 (2011)
[8]. Adah, O., Christopher, O., and Chukwudi P. O. Analysis of Extent of Awareness and Adoption of Improved OilPalm Fruit Processing Technology" in Kogi State, NigeriaJournal of Biology, Agriculture and Healthcare. 5(20); 2224-3208 (2015)
[9]. Ekine, D.I. and Onu, M.E. Economics of small-scale palm oil processing in Ikwere and Etche Local Government Areas of Rivers State, Nigeria. Journal of Agriculture and Social Research (JASR). 8 (2) 150-158 (2008)
[10]. Orhorhoro, E. K., Oyejide, J.O., and Salisu, S. Design and simulation of continuous melon fruit depodding machine.Nigerian Journal of Technological Research, 13(2): 51-57 (2018)
[11]. Orhorhoro, E.K., Odinikuku, E.W., Salisu, S.Performance Evaluation of an Improved Roasted Groundnut Seeds Decorticating Machine.Nigerian Journal of Engineering Science Research (NIJESR). 1(1): 30-39 (2018)
[12]. Asoiro, F.U., Udo, U.C. Development of motorized oil palm fruit rotary digester. Nigerian Journal of Technology 32(3), 2013
[13]. Agbonkhese, K.A., Omoikholo, F., and Okojie, G. Design and fabrication of a vertical palm fruit digester. International Journal of Current Advanced Research 7(1), 2319-6505 (2018)
[14]. Orhorhoro, E.K., Ikpe, A.E., Tamuno, R.I. Performance Analysis of Locally Design Plastic Crushing Machine for Domestic and Industrial Use in Nigeria. European Journal of Engineering Research and Science. 1(2): 26-30 (2016)

I.S. Oghenevwaire "Design and Fabrication of a Motorized Oil Palm Fruit Rotary Digester Machine"American Journal of Engineering Research (AJER), vol. 8, no. 12, 2019, pp 195-205