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DEVELOPMENT OF AN NCAM DUAL POWER PALM FRUIT DIGESTER

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Abstract

Oil palm is an economic plant with great importance due to its revenue generation capacity. One of the bottlenecks in the oil palm fruit processing in Nigeria, especially in the small scale oil palm processing industries is the digestion of the oil palm fruits. A dual powered palm fruit digester was developed in order to overcome this challenge. The major components of the digester are power source, digestion chamber, speed gear box, a shaft, outlets and a supporting frame. It was fabricated using locally sourced materials. Analysis was carried out on the digester to evaluate and ascertain its optimum performance parameters such as the output capacity and digestion efficiency. Freshly harvested palm fruit bunches were steamed and digested at 60,120 and 180 seconds digestion time. The highest attained efficiencies gotten from both the motorised and the manual pedal driven process of the machine were 81.50% and 48.17% respectively, The manual pedal mechanism makes the machine unique and distinctive in situations arising from lack of power, high cost of diesel and PMS. The machine is easy to operate, has a relatively low costs of production and it's easy to maintain. Thus it should be recommended for small and medium scale farmers mostly residing in rural areas with partial or inadequate power availability and medium scale oil palm fruit processing industries in Nigeria.

KEYWORDS**:** *Development, Performance, Digester, conventional method, efficiency.*

1.0. INTRODUCTION

Oil Palm (Elaeis guineensis) is an economic and perennial tree which originates from the tropical rain forest region of West Africa, mostly in the southern regions of Ghana and Nigeria. The fruit is made up of an outer skin (exocarp), a pulpy pores and skin (mesocarp) containing the palm oil in fibrous matrix, principal nut such as shell carp and the kernel itself contains palm kernel, which is very rich in vegetable oil (Lawal,2019).

Harvested palm bunches go through several processing stages such as sterilization, stripping, digestion and oil extraction, after which the Palm nuts and fibres by products are reprocessed into palm kernel oil (PKO), palm kernel meal (PKM) and water. With recognized economic and health significance placed on palm kernels. Palm kernel and palm kernel oil which is gotten from palm fruits is useful in making soap, glycerine, margarine, candle, pomade, oil paint, polish and medicinal drug. The palm kernel oil is likewise used in the production of fuel and biodiesel. The kernel cake alternatively serves as element for livestock feeds and it's broadly utilized in livestock industries whilst the fibres are used within the boiler as fuel (Ismail, 2015).

The key method in the oil palm production is fruit digestion. The process is done by means of which boiled or sterilized fruits are macerated for clean separation of oil from the fibre. This comprises of crushing and detachment of the heat-weakened mesocarp from fruit nuts. Digestion and oil extraction are the most tedious and critical operations in conventional palm fruit processing, consequently, early efforts of digester consists of a shaft to which stirring hands are connected and these stir and rub the palm fruits thereby loosening the pulp from the nuts and at the same time opening the oil cells of the pulp (Asha *et al*, 2017).

However, farmers and oil palm processors carry out the procedure of oil palm fruit digestion mostly by adopting the conventional method. Conventional digestion of palm fruit is often executed with the aid of mortar and pestle .These primitive techniques of digestions is commonly results to low digestion rate, it's unhygienic, time-consuming, and drudgery, which is also a low method and it's injurious to the processors (Asha *et al* 2017).

Asoiro and Udo (2013), Developed a Motorized Oil Palm Fruit Rotary Digester. The Motorized Oil Palm Fruit Rotary Digester Comprised majorly of a Feed Hopper, hammers, axle, screening plate, and a digesting chamber which was fabricated using locally sourced materials. The performance test analysis carried out on the digester showed that the capacity and efficiency was averagely 117.93kg/hr and 64.88% respectively at an optimum operating speed of 621.4rpm.

Adepoju *et al.* (2017) researched on the development of an oil palm fruit digester, the digester was fabricated and evaluated. The average capacity and the efficiency of the machine were obtained to be 330.91 kg/hr and 62.35% respectively, also suggesting that the mass of the digesting palm fruits plays a major factor in the performance parameters.

Lawal and Malachi (2019) developed and performed an assessment analysis on the Palm oil Digester. This design was based on series of experiments especially on the palm fruits to ascertain its physical properties, which aided in the determination of the machine's capacity, power requirements and other design considerations. This machine showed an average digesting capacity of about 620kg/hr and an efficiency of 62.23%.

Hence, it becomes pertinent to adopt a more flexible and dynamic mechanism towards digesting palm fruits considering the prevailing factors such as, the unavailability of electric power and the high cost of fosil fuel. The aim of the research is to develop a palm fruit digesting system with both motorised and manual pedal mechanism.

2.0. MATERIALS AND METHODS

2.1. Description and Operation of the Dual Power Oil Palm Fruit Digester

The oil palm fruit digester consists of the following major components; frame, hopper, digesting chambers, discharge outlet and the manual pedal chain mechanism.

The frame is made up of a 50 mm × 50 mm angle iron bar with a length of 1225 mm, width 523mm and height of 519 mm provides a rigid and skeletal support for the entire system

The hopper serves as an opening linking to the digesting chamber. It's a pyramidal shaped hopper with an upper width of 240mm and a base width of 136mm having a total capacity of $0.045m^3$. the conditioned palm fruit is feed in to the hopper with enters the digesting chambers. The Digesting chamber is an enclosed unit which houses the stirrer shaft and beaters. It is a cylindrical drum placed vertically with an opening to the hopper, and a downward opening serving as the discharged outlet were the digested palm fruit is collected after the digestion operation. The manual pedal chain mechanism is used to transmit power manually in situation were electric power or fossil fuel power is scarce or unavailable, thus makes the machine flexible and affordable to users.

2.2. Design considerations and assumptions;

The physical properties of the palm fruit were considered for the determination of the clearance between the auger, the beaters and the digesting chamber wall. The materials used for fabrication were locally sourced.

Materials of adequate strength and durability were used for fabrications.

The hopper shape was designed as a pyramidal frustum to avoid clogging. Based on available literatures, an optimal speed of 750rpm was considered for the design.

2.3. Design calculations

1. Hopper design

The volumetric capacity of the hopper was calculated using equation (1) given below by Olotu, F.B. (2012).

$$V = \frac{1}{3}\left(A_1 + A_2 + \sqrt[2]{A_1 + A_2}\right) \times H \qquad 1$$

Where,

V is the volume capacity in m^3, A_1 is the upper area of the hopper in m^2, and A_2 is the base area of the hopper and H is the height of the hopper measured in m.

2. Digesting unit

The volume and the diameter of the auger were calculated using the expression given by Olaoye (2011) in equation (2).

$$V = \frac{\pi D^2 L}{4} \qquad 2$$

Where V is the volumetric capacity of the auger cover in (m^3), D is the diameter of the auger cover in (m) and L is the length of the auger in (m).

3. *Pulley design*

The diameter of the pulley of the shaft was calculated using the expression given by Khurmi and Gupta (2005) in equation (3)

$$N_1 D_1 = N_2 D_2 \qquad 3$$

4. Belt design

The belt speed, v (m/s) and its total belt length, (m), were calculated using the expression given by Khurmi and Gupta (2005), respectively in the equations bellow.

$$V = \frac{\pi N D}{60} \qquad 4$$

$$L = \frac{\pi}{2}(D_1 + D_2) + 2C + \frac{(D_1 + D_2)^2}{4C} \qquad 5$$

$$C = \frac{D_1 + D_2}{2} + 0.05 \qquad 6$$

5. Torque transmitted by the shaft

The torque transmitted by the shaft was calculated using Khurmi and Gupta (2005), given equation below

$$T = F \times r \qquad 7$$

Where F is the force developed in the shaft and r is the radius of stirrer/beater shaft.

6. Power Requirement

The power requirement for the digester was determined using the expression given by Kurmi and Gupta (2005).

$P=2\Pi NT/60$ 8

Where P is the Power (Watt), N is the speed of shaft (rpm), T is the torque required to turn the shaft (Nm).

Hence the machine will involve shock load due to the digested load, the factor of safety was selected to be 1.5.

7. Tension in the V-belt

The tension in the v-belt was deduced by applying Kurmi and Gupta (2005).

$T_1/T_2 = e^{\mu\theta}$ 9

Where T_1 is the tension on the tight side of the belt, T_2 is the tension on the slack side of the belt, μ is the coefficient of friction and θ is the angle of wrap in radians.

8. Shaft design

The combine twisting moments and bending moments were used to determine the shaft diameter by applying the formula given by Khurmi and Gupta (2005)

$$T_e = ((K_B \times M)^2 + (K_T \times T)^2)^{0.5} = \pi \times S_S \times \frac{d^3}{16} \quad 10$$

Where,

T_e = equivalent twisting moment (Nm), M = resultant bending moment (Nm)

T = Torque transmitted by the gear shaft (Nm), Ss = Allowable Torsional stress with keyway = 40N/mm^2 as given by Khurmi and Gupta, (2005)

d = diameter of the shaft in mm

K_B = combined shock and fatigue factor applied to bending moment = 1.5 for minor shock

K_T = combined shock and fatigue factor applied to torsional moment =1.5 for minor shock

9. Design drawing. The orthographic view of the developed digester has been drawn using AUTO-CAD 2020 software version 23.1. The AUTO CAD drawings are shown in Figures 1-3, while the pictorial view of the digester is shown in Figure 4.

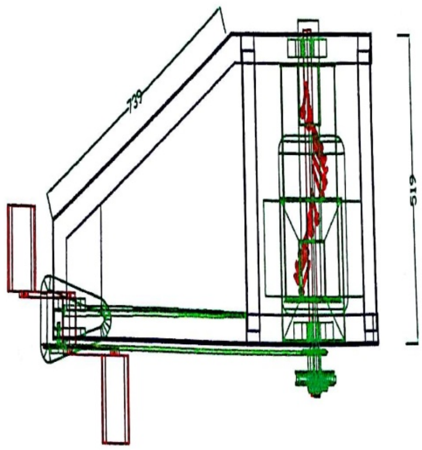

Fig.1:Top view of the machine.

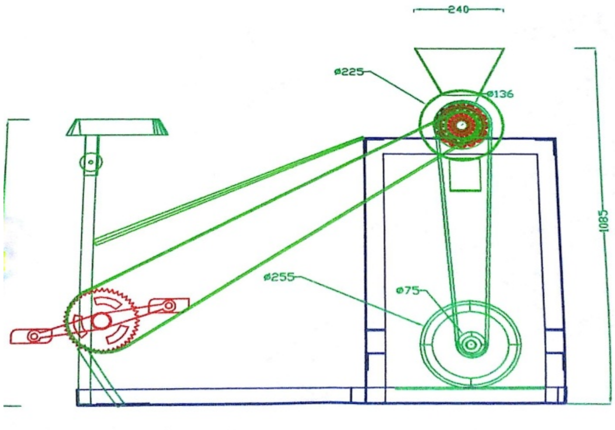

Fig.2: The side view of the machine

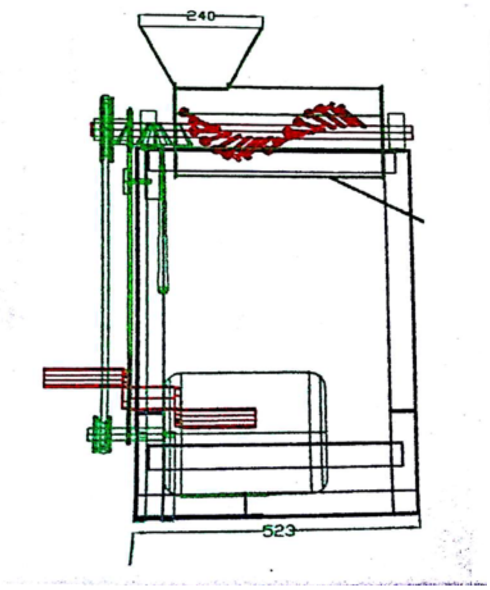

Fig.3: The front view of the machine.

Fig.4:Pictorial view of the Developed Digester.

2.4. Performance Test Analysis

A performance analysis was carried out on the developed dual power palm fruit digester. Freshly harvested palm fruit bunches were steamed for a stipulated time.

The steamed palm fruits were weighed and run at three different digestion time of 60,120 and 180 seconds at triplicates of 1.00,2.00 and 3.00kg respectively .The various weights of samples such as weight of partially, undigested and fully digested were recorded during the evaluation. The data obtained were then used to evaluate the performance parameters.

2.4.1. Performance Test Parameters

1. **Digesting Efficiency(n), D_E (%):** This determines how easy the machine is able to digest completely the steamed palm fruits and is expressed in equation (10):

$$D_E = (M_{IN}/M_T) \times 100 \quad 11$$

$$M_T = M_D + M_U \quad 12$$

Where, M_{IN} is the input mass of the palm fruit in kg, M_T is the total mass in kg, while M_U is the mass of the undigested palm fruits in kg.

2. **Output capacity, O_C, (kg/hr):** This determines the mass of the digested palm fruit received at the outlet per unit time and expressed in equation (12).

$$O_C = M_O / T \quad 13$$

Where, M_O the mass of the digested palm fruit at the outlet, (kg) and T is time taken in seconds for each of the digestion operation.

3.0 RESULTS AND DISCUSION

Tables 1 shows the results of the performance evaluation analysis carried out on the developed NCAM dual powered palm fruit digester as shown in fig 4 using freshly harvested palm fruits, which were subjected to steaming at a stipulated temperature and time.

The results showed that at 60 seconds digestion time operation, the manual output capacity, manual digestion efficiency, motorized output capacity and motorized digestion efficiency for 1.0kg of palm fruits operating at a given operation speed were 34.55kg/hr, 29.27%, 44.51kg/hr and 57.00% respectively, while using 2.00kg of palm fruits showed results of 56.59kg/hr, 27.66%, 89.42kg/hr and 58.17%. 3.00kg of palm fruit operating at the same digestion time of 60 seconds gave results of 146.61kg/hr, 25.48%, 140.52kg/hr and 64.78% respectively.

The results also showed that at 120 seconds digestion time, the manual output capacity, manual digestion efficiency, motorized output capacity and motorized digestion efficiency for 1.0kg of palm fruits operating at a fixed operational speed were 18.34kg/hr, 35.85%, 26.22kg/hr and 74.64% respectively, while using 2.00kg of palm fruits showed results of 37.24kg/hr, 36.22%, 52.35kg/hr and 74.5%. Also at 3.00kg, the results were 67.24kg/hr, 39.56%, 75.17kg/hr and 76.22% respectively.

The results showed that at 180 seconds digestion time , the manual output capacity, manual digestion efficiency, motorized output capacity and motorized digestion efficiency for 1.0kg of palm fruits operating at a fixed operation speed were 11.57kg/hr, 43.53%, 17.87kg/hr and 79.00% respectively, while using 2.00kg of palm fruits showed results of 27.44kg/hr, 40.26%, 35.13kg/hr and 81.50%. At 3.00kg gave a result of 40.77kg/hr, 48.17%, 52.60kg/hr and 81.11% respectively.

The ANOVA summary on table 2, Indicates that from the overall operations and data, the p-value gotten was far below 0.05 showing that the effect of digestion time as a factor was statistically significant, having a significant effect on the evaluating factor such as digestion efficiency and the output capacity there by disregarding the null hypothesis.

Table 1: Table 1.Performance Evaluation Test of the Developed an NCAM Dual Power Palm Fruit Digester.

S/n	Mass of palm fruit (kg)	Operational Time (secs)	Manual Output capacity (kg/hr)	Motorized Output capacity (kg/hr)	Manual Efficiency (%)	Motorized Efficiency (%)

1	1.00	60.00	34.55	44.51	29.27	57.00
2	2.00	60.00	56.59	89.42	27.66	58.17
3	3.00	60.00	146.61	140.52	25.48	64.78
4	1.00	120.00	18.34	26.22	35.83	74.67
5	2.00	120.00	37.24	52.35	36.22	74.5
6	3.00	120.00	67.24	75.17	39.56	76.22
7	1.00	180.00	11.57	17.87	43.53	79.00
8	2.00	180.00	27.44	35.13	40.26	81.50
9	3.00	180.00	40.77	52.60	48.17	81.11

Table 2: ANOVA Summary

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	6042.581	8	755.3227	0.730712124	0.663729	2.180170453
Columns	69440.29	5	13888.06	13.43554584	1.05E-07	2.449466422
Error	41347.21	40	1033.68			
Total	116830.1	53				

Fig.5 showing a visualized effect of the digestion time on the evaluating factors, indicated that at 60 seconds digestion time, the manual output capacity, motorized output and motorized efficiency were highest at 3.00kg and were lowest at 1.00kg which explains that the quantity of the input mass is directly related to the output capacity furthermore the high manual output capacity in 3.00kg was as a results of materials left over in the machine during the manual pedal operation on preceding masses, which gave rise to material logs in the machine.

The motorized efficiency was higher than the pedal manual efficiency in all processes but was highest at 3.00kg, indicating that the palm fruits products at several masses were affected and efficiently digested compare to the manual pedal operation which maintained relatively low digestion efficiency for all digestion operation.

Hence for 60 seconds digestion time operation, the efficiency of the machine increases with the increase in mass or volume of the input mass of the palm fruits.

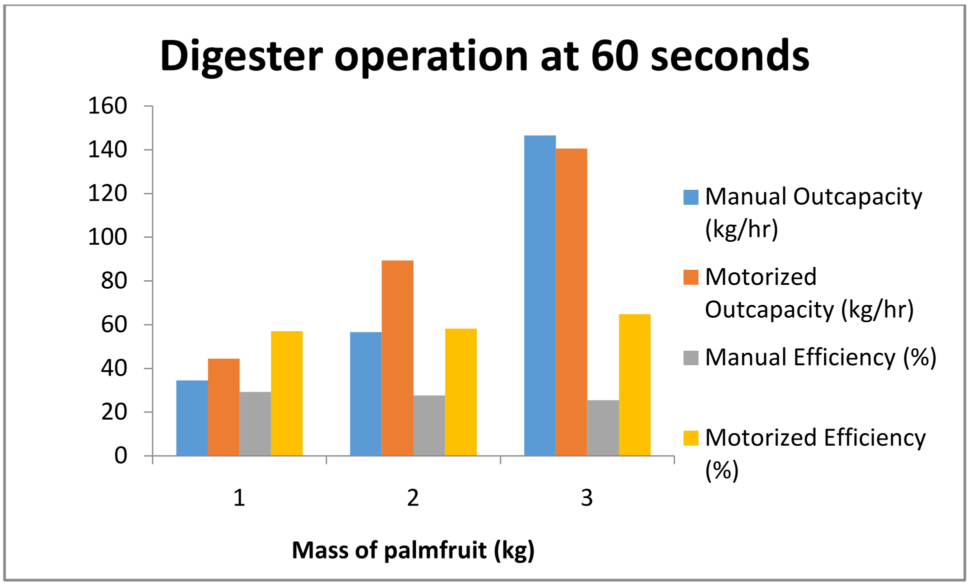

Fig 5: Digester Parameters at 60 Seconds digestion Time

Fig.6 showing results of the digestion time on the evaluating factors, indicating that at120 seconds digestion time, the digestion efficiency was highest at all levels using a motorized mechanism. The motorized output capacity was highest at 3.00kg and lowest at 1.00kg. a high manual output capacity in 3.00kg was observed, which correlate that the quantity of the input mass is directly related to the output capacity furthermore this was as a results of materials left over in the machine during the manual pedal operation on proceeding masses, which gave rise to material logs in the machine.

Hence for 120 seconds digestion time operation, the efficiency of the machine increases with the increase in mass or volume of the input mass of the palm fruits.

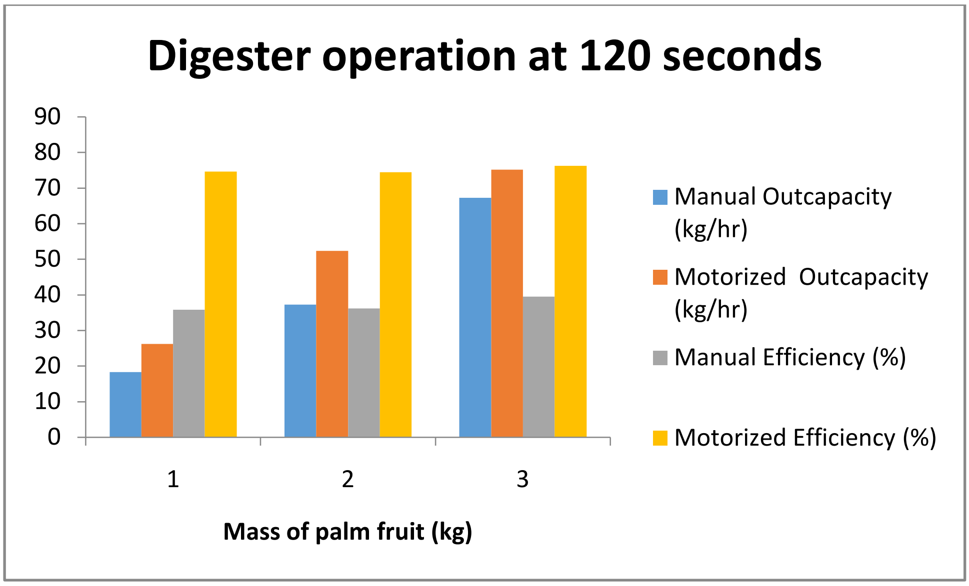

Fig 6: Digester Parameters at 120 Seconds digestion Time

Fig.7 showing the effect of the digestion time on the evaluating parameters, which indicated that at 180 seconds digestion time, the digestion efficiency was highest at all levels using a motorized mechanism.

Hence for 180 seconds digestion time operation, the efficiency of the machine increases with the increase in mass or volume of the input mass of the palm fruits.

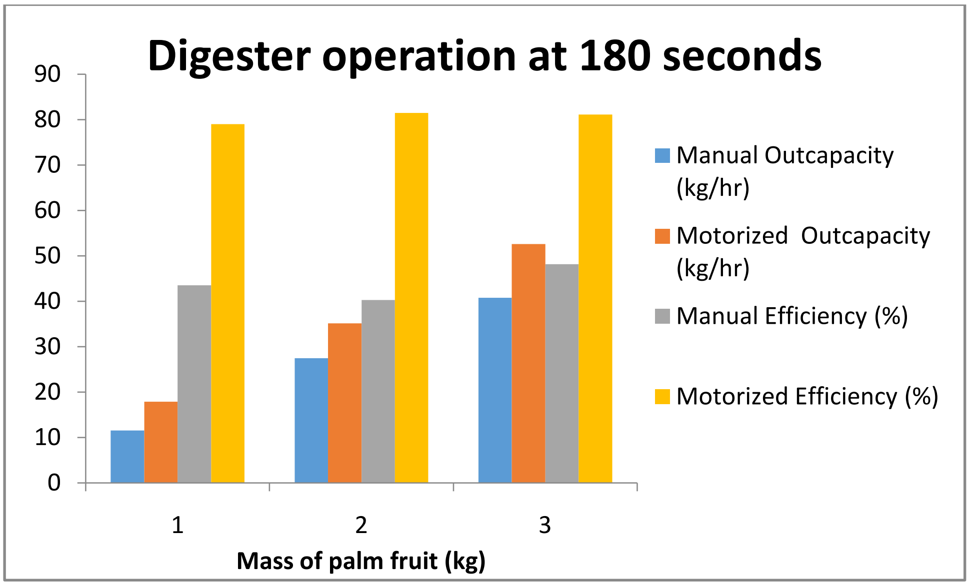

Fig 7: Digester Parameters at 180 Seconds digestion Time

5.0 CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The NCAM dual powered palm fruit digester was developed and evaluated. The palm fruit digester was developed using locally sourced materials with adequate strength and stability. A performance analysis was carried out on the palm fruit digester using three time levels for the digestion duration. Results obtained during evaluation showed that the highest digestion efficiency obtained for the machine was at the range of 81.11 and 81.50% using the motorized mechanism of the machine, also having the highest output capacity. The results from the evaluation indicated that the digestion time played a significant role on the digester efficiency and output capacity. This machine is safe and easy to operate and relatively cheap ,and is capable of handling larger quantity of palm fruit product, thus, making it suitable for use by the small and medium scale processing industries in Nigeria.

5.2. Recommendation.

Further evaluations should be carried out on the machine with a wide range of varying machine operational speed range.

REFERENCE

Adepoju B. F., Oludare S. D. and Ibrahim, A. H. (2017). Development and Performance Evaluation of an Oil Palm Fruit Digester; *Bioprocess Engineering; 1(2): 4953.*

Asha, S. O., Obasha, I.O., Emmanuel, S. O, and Ayewa. O.A. (2017); Design and Development of a Continues Palm Nuts Digesting Machine; *Science Arena Publications Specialty Journal of Engineering and Applied Science* Available online at www.sciarena.com 2017, Vol, 3 (4): 1-19.

Asoiro, F. U. and Udo, U. C. (2013); Development of Motorized Oil Palm Fruit Rotary Digester; *Nigerian Journal of Technology (NIJOTECH), Vol. 32. No. 3. pp.* 455 – 462.

Bello, R. S., Bello, M. B., Essien, B. A. and Saidu, M. J. (2015), Economic Potentials of Oil Palm Production and Machinery Use in UDI, Enugu State, Nigeria, *Science Journal of Business and Management. Special Issue: Sustainable Entrepreneurial Developments in Agribusiness. Vol. 3, No.5-1, pp. 16-20.*

Food Agriculture Organization. Small scale palm fruit processing, *FAO, Agricultural Services Bulletin 148, 2002.*

Ismail, S. O., Ojolo, S. J., Orisaleye, J. I., Adediran, A. A., and Fajuyitan, O. O.(2015); Design and development of an improved palm kernel shelling and sorting machine *European International Journal of Science and Technology Vol. 4 No. 2 ;*225.

Khurmi, R. S. and Gupta, J. K. (2005), Textbook of Machine Design; *Eurasia Publishing House (Pvt.) Ltd: New Delhi. pp 53-86, pp 120-180, pp 181-223 and pp 509-758.*

Lawal, A.S. and Malachi, I.O. (2019), Development and Performance Assessment of an Improved Palm Oil Digester. *International Journal of Technical & Scientific Research Engineering* www.ijtsre.org Volume 2 Issue 2.

Nwankwojike B. N, Odukwe A. O, Agunwamba C. J.(2012); Design, Fabrication and Evaluation of Palm Nut-Pulp Separator; *Journal of Emerging Trends in Engineering and Applied Sciences* (JETEAS) *3 (1): 144-151© Scholar link Research Institute Journals, 2012 (ISSN: 2141-7016)jeteas.scholarlinkresearch.org.*

Ogblechi, S. R and Ige, M. T. (2014), Development of a Model to Predict the Sheer Force of a Horizontal Mechanical Digester. *International Journal of Science, Technology and Society,* Vol.2, No. 6, pp. 174-178.