The Effects of a Four-Arm Hammer Cracker/ Beater on the Performance of a Palm Kernel Cracking Machine

Alexander A. Offiong, Aniekan Offiong, Idorenyin .E. Markson, and A.P. Ihom
Department of Mechanical and Aerospace Engineering,
Faculty of Engineering, University of Uyo, Uyo-Nigeria.
Corresponding Author's Email and Phone Number:
ihomaondona@uniuyo.edu.ng +2348035813571
DOI:10.56201/ijemt.v10.no7.2024.pg29.43

Abstract

The effects of a four arm hammer cracker/ beater on the performance of a newly developed palm kernel cracking machine has been investigated. The work evaluated the performance of the machine with the four arm hammer head attached to it under constant load test. The shaft cracking speed was however, varied from 800 -1600 rpm during this period several parameters were measured. The result showed that as the shaft speed was increasing the cracking time of the palm kernel shells was decreasing. The shortest cracking time of 29.20 seconds occurred at a shaft speed of 1600 rpm while processing 3000g of palm kernels. At a shaft speed of 800 rpm the number of whole nuts was 473, this number increased to 529 at 1000 rpm and continued to decrease to 209 at 1600 rpm. At a shaft speed of 800 rpm the number of un-cracked nut was 21 as the speed continue to increase the number of un cracked nut decreased to 11 at 1000 rpm and continue to decrease to 1 at 1600 rpm, which means as the speed increases the number of un-cracked nut decreases. The work also discovered that the highest effective capacity using the four arm hammer beater was 102.74 and occurred at the shaft speed of 1600 rpm, likewise the highest cracking efficiency of 99.84 occurred at 1600 rpm. The highest performance efficiency of 82.66 however, occurred at the four arm hammer speed of 1000 rpm, considering other measured parameters like, number of whole nuts, number of broken nuts, performance efficiency, split nut loss, and overall efficiency the work concluded that the best operating speed for the newly developed palm cracker machine using the four arm hammer beater is 1000 rpm.

INTRODUCTION

A palm oil mill produces palm oil and palm kernel nuts as primary products and bio mass as secondary product. Due to the continuous increase in demand for palm kernel nuts for cream, soap and cooking oil, as a result of increasing human population, there is a corresponding increase in the demand for quick and easy cracking/separation of palm kernel nut from its shell. The manual method where palm kernel nuts are cracked using stones is labour intensive, time consuming, cumbersome and very slow to meet the demands of growing industries. With the present economic reality in Nigeria, imported machines for cracking palm kernel nuts are very expensive for the small scale mills to buy (Ndegwe, 1987; Babatunde and Okoli, 1988; Babatunde *et al.*, 1988;

FAO, 2002; FAO, 2004; Okoli, 2022). Hence, there is the need to design and develop a palm kernel nut cracking machine using local available raw materials such as discarded automobile spare part with relatively less production cost. It is important to note that the efficiency, capacity and output/hour of the palm kernel nut cracking machine depends on several factors, but in this work emphasis is on shaft speed and the type of cracker hammer/beater used (Offiong, 2024). These two factors influence on the quality of cracked palm kernel nuts will be of great significance to palm kernel nut cracking machine producers, since it will help them decide on the optimum number of arms a hammer cracker/ beater should have for quality cracking of palm kernel nuts (Antia *et al.*, 2014; Andoh *et al.*, 2015; Apeh *et al.*, 2015; Offiong, 2024).

There are three common varieties of palm kernel nuts. *Dura, Pisifera* and *Tenera*. The *Tenera* is a hybrid of the Dura and the Pisifera. The Dura palm have kernels with a thick shell, the Pisifera palms have kernels with no shell, while the Tenera palm have kernels with a thin shell (Anyane, 1966; Asoiro and Udo, 2013). In Nigeria it is the *Tenera species* that is commercially planted hence this research will design and developed a cracker for the Tenera species which is usually between 7-15 mm in length with shell thickness of 1.2mm. The palm tree is one of the greatest economic assets a nation possesses. The oils produce from oil palm namely palm oil and kernel oil are used for oil paints, margarine, candle, polish, soap making, glycerin and medical purposes. Oil palm are also used to produce biodiesel. The palm kernel shells are used as a source of energy by blacksmiths and other industries. They palm kernel shells are also used for making brake pads. Also the palm kernel cakes are used in making livestock feeds which are very rich in the essential nutrients required by livestock. For details on the uses of oil palm tree products see (Mba *et al*, 2015; Mosarof *et al*, 2015; Asadullah *et al*, 2014; Adebayo 2004, Emeka and Julius 2007, and Norazura 2017). According to (Badmus, 1991) Nigeria's oil palm exist in small oil palm plantation and wild groove, even though recently some large scale plantations have been developed. The need of oil palm processing machines suitable for small scale mills cannot be over emphasis. Machine involved in the palm oil mill process are: palm fruit sterilizer, palm fruit thresher, palm fruit digester, palm oil press machine, palm kernel cracker, palm kernel separator machine and palm kernel oil expeller machine. The design and development of these machines for large scale production has been the subject of many research work. This has resulted in the manufacture of sophisticated and complicated foreign made palm oil processing machines which are not suitable for our small scale production System.

This project is concern with investigating the effects of a four-arm hammer cracker/ beater in a newly developed palm kernel nut cracking machine on the machine performance, quality of nuts produced and output when shaft speed is varied.

2.0 MATERIALS AND METHOD

2.1 Materials

The materials and equipment used for this work include the newly designed and produced palm kernel cracking machine, four arm beater head, timer, dried palm kernel nuts, collecting pans, sorters, tachometer for measurement of speed, and Microsoft Excel 210 of window 7 software. The newly developed machine and the four arm beater head can be seen in Figures 2.1-2.3.

Description of the functional Components of the Newly Developed Cracker

The functional components of the newly developed cracker machine are: Hopper, Cracking Chamber, Power Transmission Shaft, bearing and bearing housing, pulley, and cracking mechanism.

A. **Hopper**: The hopper is connected to the conveying channel that leads to the cracking chamber. It is constructed as a truncated square base pyramid with mild steel sheet metal of 1.4mm gauge.
B. **Cracking Chamber**: The cracking chamber is cylindrical in shape with diameter 370 mm. It is made of a mild steel plate of 3mm thickness. The front and the rear ends of the chamber are covered with circular plates of the same material, thickness and diameter. The internal walls of the cylinder are lined with 12mm iron rods to form the cracking ring.
C. **Power Transmission Shaft**: The power transmission shaft is made of a 25mm diameter by 1200mm length rod of tool steel with a 4-arm beater welded to one end and a pulley pinned down the other end with a pillow bearing.
D. **Bearing and Bearing Housing:** Two UC 206, 30mm diameter pillow block bearing are used. The bearing housing is used to hold the bearing firmly to the frame, while the bearing itself holds the shaft in position to minimize fiction during rotation.
E. **Pulley:** Two pulleys of different diameters are used in the design. The pulley is the device that transmit power from prime mover to the cracking mechanism shaft, via two v-belts. The smaller pulley connected to the prime mover is 50mm in diameter while the larger pulley connected to the shaft of the cracking machine is 80mm in diameter.
F. **Cracking Mechanism**: The 4-arm hammer cracks the kernel nut by beating it against the wall of the cracking chamber. The walls of the cracking chambers are lined with 12mm iron rods to form the cracking ring. The hammers are placed at the angle 180^0, or 90^0 of 120^0 to each other around the shaft. The rotation of the shaft enable the hammers to hit the kernel laterally and let out the seed from the palm nut in a neat form (Offiong, 2024). See Figure 2.3 for the complete views of the four arm beater head/ shaft.

Operating Principles of the Newly Developed Palm Kernel Cracker

The Palm Kernel nuts are fed into the cracking chamber through the hopper, and the hoppers slanting nature facilitates the smooth movement of the kernels as feeding continues. Power is transmitted to the rotor from the prime mover through the v-belt. As the nut are fed from the hopper at moderate speed through the centralized hole in the flywheel, the centrifugal rotating four arms hammer beats the palm kernel against the cracking chamber giving rise to a very great impact force that eventually cracked the palm nuts. The cracked kernels and shells thereafter passed into the lower circumference of the cracking chamber and are collected for separation. Figure 2.1 shows the newly produced palm kernel nut cracking machine and Figure 2.2 shows the exploded view of the newly developed machine.

Figure 2.1: Three dimensional model of the developed palm kernel nut cracking machine

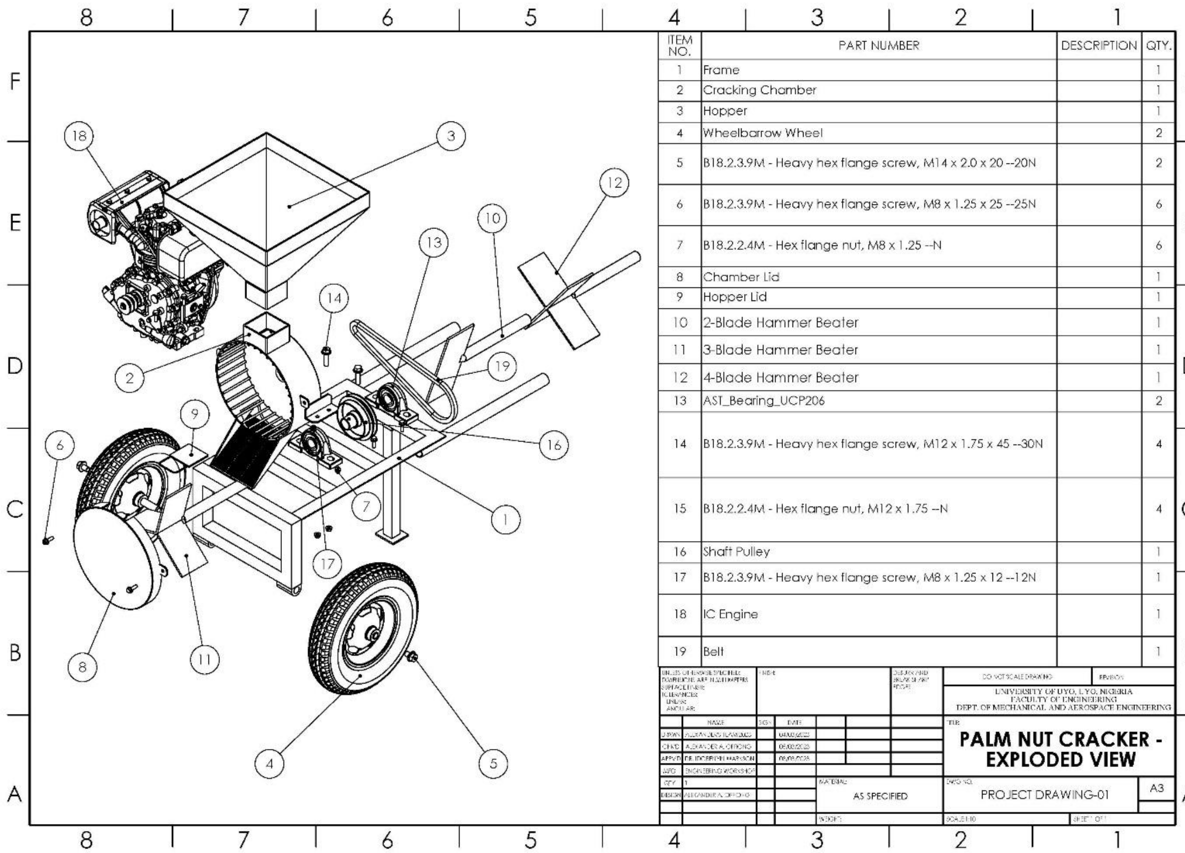


Figure 2.2: Exploded view of model components of the developed palm kernel nut cracking machine

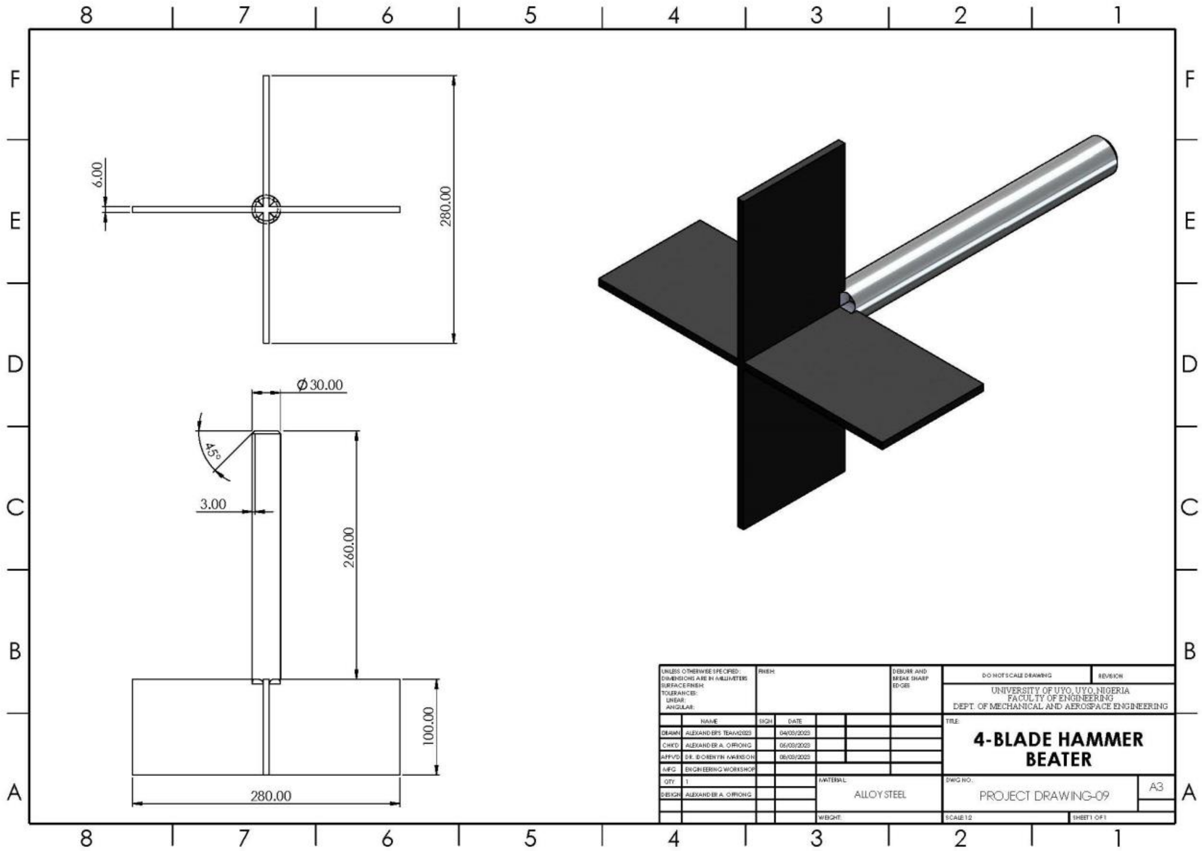


Figure 2:3 Components drawing showing Four Blade Hammer Shaft or Beater Shaft Head

2.2 Method

Determination of evaluation parameters

Evaluation parameters for the developed crackers include Effective capacity (EC), cracking efficiency (CE), performance efficiency (PE), split-nut loss (%), (SL), (UL), un-cracked less (%); and overall efficiency (OE). These parameters can be calculated using equation (15-20) respectively.

$$EC = M/T \quad - \quad - \quad - \quad (15)$$

$$CE = [N_{cr} / N_{to}].100 \quad - \quad - \quad - \quad (16)$$

$$PE = [N_{wh} / N_{to}].100 \quad - \quad - \quad - \quad (17)$$

$$SL = [N_{br} / N_{to}].100 \quad - \quad - \quad - \quad (18)$$

$$UL = [N_{uc} / N_{to}].100 \quad - \quad - \quad - \quad (19)$$

$$OE = CE \times PE \quad - \quad - \quad - \quad (20)$$

$$N_{br} = N_{to} - (N_{wh} + N_{uc}) \quad - \quad - \quad (21)$$
$$N_{cr} = N_{wh} + N_{br} \quad - \quad - \quad - \quad (22)$$

Where M is total mass of palm nuts fed into the hopper (kg); T is total time taken by the cracked mixture to leave the chute (h) [Cornish, 1991]; N_{to} is the total number of kernel nuts fed into the hopper; N_{cr} is the total number of cracked kernel [damaged and undamaged] after cracking; N_{wh} is the number of whole [un-broken] kernel nut after cracking; N_{br} is the number of broken kernel nuts after cracking; and N_{uc} is the total number of un-cracked kernel nuts after cracking. In the experiment a constant volume of kernel to which N_{to} and M has been assigned will be employed and equation (21) and equation (22) will be used in the calculation of N_{br} and N_{cr} respectively. This means that for every cracking operation during the experiment only shaft speed, N_{wh}, N_{cu}, and the cracking time T will be recorded. N_{br} and N_{cr} will have to be calculated.

Experimental Procedure

A constant volume cylindrical container of diameter of 0.174m and height 0.180m is used in measuring the palm kernel nut for the cracking experiment. The container was examined and found to contain an average of 640 palm kernel nuts weighing 3000grams at full load. Using this container 640 palm kernel nuts were used to test the developed palm kernel cracking machine when assembled with four arm hammer beater. Speed was determined by the use of a tachometer. The procedure is that each set of the 640 palm kernel nuts was cracked at the shaft speed of 800, 1000, 1200, 1400 and 1600 rpm and the total number of whole kernel nuts and total number of un-cracked kernel nuts sorted. In each case the total mass of palm kernel nut fed into hopper together with the time taken by the cracked mixture to leave the chute was recorded. These data were then analyzed using Microsoft excel 210 of window 7.

3.0 RESULTS AND DISCUSSION

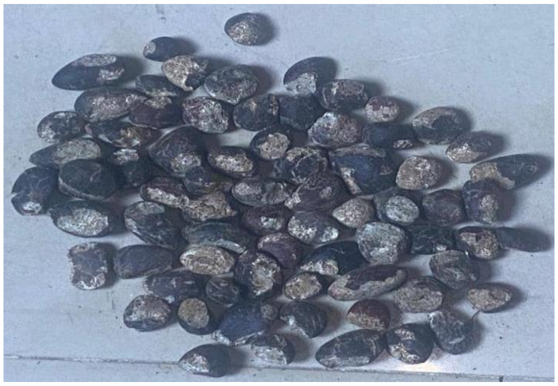
3.1 Results

The result of the test using four –arm cracking shaft is shown below:

. Figure 3.1 shows the test run results of the developed palm kernel nut cracking machine (a) Un-separated cracking palm kernel shells and nuts after cracking; (b) Sample of whole [un-broken] kernel nuts after cracking; (c) Sample of broken kernel nuts after cracking; and (d) Sample of un-cracked kernel nuts after cracking operation. Table 3.1 and Table 3.2 shows the data obtained from the experiment carried out to determine the performance of the developed palm kernel nut cracking machine at the speed of 800, 1000, 1200, 1400, and 1600rpm when assembled with a four arm hammer beaters. Figure 3.1 is the graph of machine efficiencies against speed when the machine is assembled with four arm hammer beater.

(a) Un-separated cracking palm kernel shells and nuts after cracking

(b) Sample of whole [un-broken] kernel nuts after cracking



(c) Sample of broken kernel nuts after cracking

(d) Sample of un-cracked kernel nuts after cracking

Figure 3.1: Test run results of the developed palm kernel nut cracking machine (a) Un-separated cracking palm kernel shells and nuts after cracking; (b) Sample of whole [un-broken] kernel nuts after cracking; (c) Sample of broken kernel nuts after cracking; and (d) Sample of un-cracked kernel nuts after cracking

Table 3.1: Data obtained from the experiment carried out to determine performance of the developed palm kernel nut cracking machine when assembled with four arm hammer beater

Shaft speed in rpm	No. of palm kernel nuts (N_{to})	Mass of Kernels (M) in (g)	Cracking Time (T) in (s)	Number of whole nuts (N_{wh})	Number of un-cracked nut (N_{uc})	Number of broken nuts (N_{br})	Number of cracked nuts (N_{cr})
800	640	3000	33.50	473	21	146	619
1000	640	3000	32.24	529	11	100	629
1200	640	3000	31.21	368	8	264	632
1400	640	3000	30.54	267	6	367	634
1600	640	3000	29.20	209	1	430	639

Calculations: (1) $N_{br} = N_{to} - (N_{wh} + N_{uc})$;
(2) $N_{cr} = N_{wh} + N_{br}$

Table 3.2: Performance tests for the developed palm kernel nut cracking machine when assembled with four arm hammer beaters.

Shaft speed in (rpm)	No. of palm kernel nuts (N_{to})	Mass of Kernels (M) in (g)	Cracking Time (T) in (s)	Effective Capacity(EC) in (g/s)	Cracking efficiency (CE)	Performance efficiency (PE)	Split-nut loss % (SL)	Un-cracked nut loss % (UL)	Overall Efficiency (OE)
800	640	3000	33.50	88.23	96.72	73.91	22.81	3.28	71.49
1000	640	3000	32.24	92.19	98.28	82.66	15.63	1.72	81.24
1200	640	3000	31.25	96.00	98.75	57.50	41.25	1.25	56.78
1400	640	3000	30.54	98.23	99.06	41.72	57.34	0.94	41.32
1600	640	3000	29.20	102.74	99.84	32.66	67.19	0.16	56.19

Calculations: (1) EC = M/T; (2) CE = $(N_{cr}/N_{to}).100$; (3) PE = $N_{wh}/N_{to}).100$; (4) SL = $(N_{br}/N_{to}).100$; (5) UL = $(N_{uc}/N_{to}).100$; (6) OE = CE x PE.

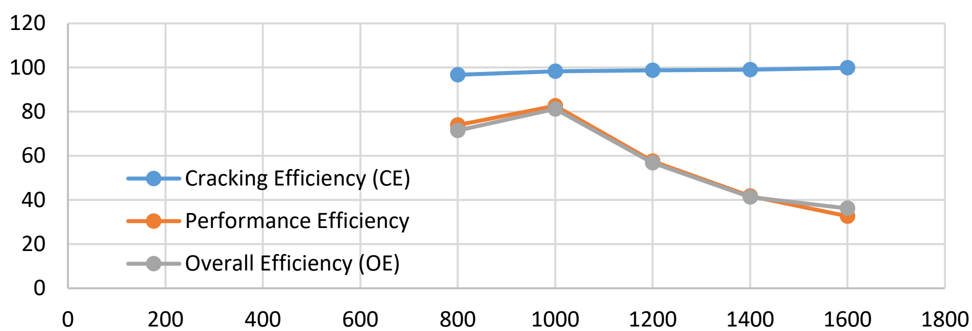


Figure 3.2 Graph of machine efficiencies against speed when the machine is assembled with four arm hammer beaters

3.2 Discussion

Table 3.1 shows the data obtained from the experiment carried out to determine performance of the developed palm kernel nut cracking machine when assembled with four arm hammer beater. The data show that at the operational shaft speed of 800 rpm the cracking time of the palm shell nuts was 33.5 seconds. As the speed continued to increase the cracking time was decreasing and when it got to 1600 rpm, it took only 29.20 seconds to accomplish the cracking. At a shaft speed of 800 rpm the number of whole nuts were 473, as the operational speed increased to 1000rpm the number of whole nuts increased to 529 and then continued to decrease as the speed increases to 209 at 1600 rpm operational speed. At a shaft speed of 800 the number of un-cracked nut were 21. The number of un-cracked nut decreased to 11 at 1000rpm and continued to decrease to 1 at 1600 rpm. At a shaft speed of 800 the number of broken nuts were 146. The number of broken nuts decreased to 100 at 1000 rpm and then continued to increase as the speed increases to 430 at 1600 rpm. At a shaft speed of 800 rpm the number of cracked nuts were 619. The number of cracked nuts then increased to 629 at 1000rpm and continue to increase as the speed increases to 639 at 1600 rpm. The inference of the result shows that the best operating speed for the four arm beater is 1000 rpm, although shorter cracking or processing time can be obtained at 1600 rpm (Akubo, 2002; Fashing *et al.*, 2017; Alade *et al.*, 2020). The observed inference agrees with the work of many researchers including Offiong (2024) who all agree that the best operating speed for the four-arm cracker hammer head is 1000 rpm this is because losses are minimized at this speed (Ologunagba, 2012; Udo *et al*., 2015; Ibrahim *et al*.; 2016; Ibiyeye, *et al*, 2022).

Table 3.2 further shows the performance tests carried out on the developed palm kernel nut cracking machine using four arm beater hammer head. As the operational speed was increased from 800rpm- 1600rpm the effective capacity in g/s was increased from 88.23g/s at 800rpm to 102.74g/s at 1600rpm. The increase in operational speed from 800- 1600rpm also affected the cracking efficiency which increased from 96.72 – 99.84. The performance efficiency however, increase from 73.91 at 800rpm and attained the highest value of 82.66 at 1000rpm and then continued to decrease to 32.66 at 1600rpm. The increase in operational speed showed that split-nut loss % at 800rpm was 22.81% this value dropped to 15.63 at 1000rpm and thereafter the split-nut losses increase with increase in operational speed to the value of 67.19 % at 1600rpm. The increase in operational speed also affected un-cracked nut loss %, at 800rpm the value of un-cracked nut % was 3.28% as the speed increased, at 1000rpm there was a drastic drop to 1.72%, this was followed by a gradual drop to 0.16% at 1600rpm. The overall efficiency of operating the developed palm kernel nut cracking machine showed that as the operational speed was increased from 800rpm the overall efficiency was 71.49, this increased to 81.24 at 1000 rpm subsequently the overall efficiency of the developed machine dropped with increase in operational speed to 56.19 at 1600rpm, this value was higher than 41.32 at 1400 rpm, which means there was increase in overall efficiency at 1600 rpm. This may not be unconnected with the fact that the speed of 1600 rpm has the shortest processing time of 29.20 seconds to crack the palm kernel shells. The above trend which has been observed during the testing of the machine has equally, been observed by several other authors as noted in the references (Ologunagba, 2012; Ibrahim *et al*.; 2016; Ibiyeye, *et al*, 2022). Udo *et al*, (2015) developed a palm kernel nut cracking machine for rural use; performance evaluation of the machine indicated that the throughput of the machine increased from 10.91 to 38.00g.s as the speed increased from 800 to 2400 r/min. The performance efficiencies of the palm nut cracker machine developed were 93%, 94%, 95%, 94.5% and 94% at set speed of 800, l200, 1600, 2000 and 2400 r / min. respectively. The analysed parameters are still overwhelmingly in favour of operating the four arm beater shaft at an operational speed of 1000 rpm.

Figure 3.2 is a further illustration of the graph of palm kernel cracking machine efficiency against operational speed of the machine. The cracking efficiency increased with the operational speed, while the performance efficiency peaked at operational speed of 1000rpm and then gradually decreased with operational speed down to 32.66 at 1600rpm. The same trend is observed with the overall efficiency which peaked at operational speed of 1000rpm and then gradually reduced to 41.32 at 1400 rpm. The overall efficiency however, picked up again as it moved to 56.19 at 1600 rpm. This may not be unconnected to the easy and short time required to crack palm kernel shells at 1600 rpm. Many researchers in carrying out the performance analysis of their produced palm kernel nut cracking machine also observed these trends (Udo *et al.*, 2015; Taofik *et al.*, 2019; Ibiyeye, *et al*, 2022; Offiong, 2024).

4. CONCLUSIONS

The effects of a four–arm hammer cracker / beater on the performance of a palm kernel cracking machine has been investigated and the following findings drawn from the investigation:

1. The four arm hammer cracker / beater has performed very well in the newly developed cracker machine for cracking palm kernel shells.

2. It took the four arm hammer only 29.20 seconds at the operational speed of 1600 rpm to crack 3000g of palm kernel shells.

3. The study discovered that the best operational speed for operating the newly developed palm cracker machine with the four arm hammer head was 1000 rpm, this is because at this speed minimal losses occur to the cracked palm kernel shells; un- cracked nuts loss are minimal, split nut loss % is minimal, overall efficiency is highest (81.24) and performance efficiency is highest (82.66).

4. Using the four arm cracker/ beater in the newly developed cracker machine, the machine attained a cracking efficiency of 99.84 at 1600 rpm

5. Using the four arm cracker / beater in the newly developed cracker machine, the machine attained effective capacity of 102.74g/s at 1600 rpm

6. As the operational speed increased while using the four arm cracker/ beater on the newly developed machine the number of whole nuts increased to 529 at 1000 rpm and decreased to 209 at 1600 rpm.

7. As the operational speed of the four arm cracker on the newly developed machine increases the number of cracked nut also increases attaining the highest value of 639 at 1600 rpm.

REFERENCES

Adebayo, A. A. (2004). *Development and Performance Evaluating of a Motorized palm Nut cracking machine.* Proceeding of the Annual Conference, Nigeria Institution of Agricultural Engineers. Vol. 26, pp. 326-330.

Akubuo, C. O., Eje, B. E. (2002). Palm kernel and Shell Separator. Bio-systems Engineering, 81(2), 193-199. Doi:http://doi.org/10.1006/bioe.2001.0029.

Alade, E. I., Koya, O. A., and Omidiji, B. V., (2020). Development of a modified palm-nut cracker. Agricultural Engineering International: CIGR Journal, 22(1), pp. 204-214.

Andoh, P. Y., Agyare, W. A., and Dadzie, J. (2015) selection of an ideal mesh size for the cracking unit of a palm kernel processing plant. Journal of Science and Technology. Vol. 30 No.3, pp. 109-118.

Antia, O. O; Olosunde, W., and Offiong A. (2014). Determination of optimum moisture content of palm nut cracking for efficient production of whole kernel. Nigerian Journal of Technological Development, vol. 11, No. 2, pp. 27-30.

Anyane, S. L. (1966) The Oil Palm Industries of West Tropical Africa. PhD Dissertation at Stanford University.

Apeh, F. I., Yahaya, B. S., Achema, F., Fabiyi, M. O., and Apeh, E. S. (2015). Design analysis of a locally fabricated palm kernel shells grinding machine. American Journal of Engineering Research. 4(11), 1-7.

Asadullah, M., Adi, A. M., Suhada, N., Malek, N. H., Saringat M. I., and Azdarpour, A. (2014) "Optimization of palm kernel shell torrefaction to produce energydensified bio-coal," energy Conversion and Management, vol. 88 pp. 1086-1093, 2014.

Asoiro, F. U and Udo, U. C (2013). Development of motorized oil palm fruit rotary digester. Nigerian Journal of Technology, vol. 32. No 3, pp. 455-462.

Babatunde, O. O. and Okoli, J. O. (1988). "Investigation into the effect of nut size on the speed needed for cracking palm nut in centrifugal nut cracker, "*Nigerian Journal of Palm and Oil Seeds,* vol. 9, pp. 84-88.

Badmus, G. A. (1991) "NIFOR Automated Small Scale Oil Palm Processing Equipment, its need, development and effectiveness "Proceeding of PORIM INTERNATIONAL Palm Oil Conference, Nigeria 9-14 September 1990, Nigeria.

Babatunde, O. O., Ige, M. T., and Makanjuola, G. A., (1988). Effect of sterilization on fruit recovery in oil palm fruit processing. Journal of Agricultural Engineering Research, vol. 41, Issue 2, pp. 75-79.

Cornish, E. H. (1991). Materials and Designer, Cambridge University Press, Cambridge, 28-29.

Emeka, V. E. and Julius .O.M. (2007). "Nutritional Evaluation of Palm Kernel Meat Types1. Proximate Composition and Metabolizable energy Values," A*frican Journal of Biotechnology* vol. 6, issue 21, pp. 2484-2486.

Fashing, A. B; Disdrodola, O. S; and Hammed, I. A., (2017). Development and performance evaluation of and oil palm fruit digester, Bioprocess Engineering 1(2): 49-53. http://www.sciencepublishinggroup.com/j/be doi:10.11648/j.be.20170102.13.

Food and Agricultural Organization (2002) Statistical Yearbook. *Journal for Food and Agricultural Organization, 2/2.*

Food and Agricultural Organization (2004) Statistical Yearbook. *Journal for Food and Agricultural Organization, 2/2.*

Ibiyeye, D., Dlunloyo, O., Aderemi, A., Emmanuel, I., Akala, A., and Owolola, O. (2022). Design and development of a palm kernel nut unit. Technology audit and Production Reserves, 1/3(63), pp. 30-44, doi:http://doi.org/10.15587/2706-5448.2022.253931.

Ibrahim, I. D., Jamiru, J., Sofuwa, O., and Onuoha, O. J., (2016). Design and performance evaluation of horizontal-shaft palm kernel cracking machine. Proceeding of Covenant University-3rd International Conference on African Development. Issues. pp. 337-3341.

.

Mba, O. I., Dumont, M. J., Ngadi, M. (2015) "Palm Oil Processing, characterization and utilization in the food industry – A review, "Food Bioscience, Vol. 10, pp. 26-41.

Mosarof, M. H., kalam, M. A., Masjuki, H. H., Ashraful, A. M., Rashed, M. M., Imadadul, H. K., Monirul, I. M. (2015). "Implementation of palm biodiesel based on economic aspects, performance, emission, and wear characteristics, Energy," Conversion and Management, Vol. 105 pp. 617-629.

Ndegwe, N. A., (1987). The oil Palm in Rivers State of Nigeria. Pp: 103-104.

Norazura, A. M. H. (2017). Usage of palm oil, palm kernel oil and their fractions as confectionery fats. *Journal of Oil Palm Research*, 29(3), 301-310. Dio: http//dio.org/10.21894/jopr.2017.2903.01.

Offiong, A. (2024) Design and Production of Palm Kernel Cracking Machine, Undergraduate Project work in the Department of Mechanical and Aerospace Engineering, University of Uyo-Nigeria for the award of B.Eng. Degree.

Okoli, J. U. (2022). Optimum during time for palm nuts for efficient nut cracking in small scale oil palm fruit processing mills. Global Journal of Engineering Research. Vol. 2, No. 1, 2003, pp. 7-10.

Ologunagba F. O., (2012). Design and Evaluation of a Horizontal shaft palm nut cracking machine. *Journal of Engineering and Applied Science, Vol. 4, pp 81.*

Taofik, O. K; Adesola, O. K; Abu, R., and Olantunde, A. N., (2019). Development and performance evaluation of small-scale palm kernel cracker. International Journal of Mechanical and Civil Engineering, vol 2, Issue 1, pp. 15-27.

Udo, S. B., Adisa, A. F., Ismila, S. O and Adejujyibe, S. B., (2015). Development of palm kernel nut cracking machine for rural use. Agric Eng Int: CIGR Journal 17(14): 379-388.