An electrically operated kola nut pods breaking machine

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Abstract: Kola nut pod breaking is a very tedious task manually; therefore its mechanization is essential for effective processing. The objectives of this study are to design and fabricate a kola nut pod breaking machine and performance evaluation of kola nut pods breaking machine. Some physical and mechanical properties required for machine design were determined using standard methods. The machine was powered by an electric motor, with the hammer attached to the shaft using a drum with a rope tension of 171.68N, cross–sectional area of 5.027 x 10-5 m^2 and 3414.90 kN/m^2 tensile stress. The speed of the machine used by the pulley was 308.57 r/min to operate. The machine was evaluated by using one to four pods at a time, and was replicated four times.

The average moisture content was 68.87% wet basis. The average length, breadth, width and thickness were 108.54±7.79, 60.60±13.31, 46.97±10.23 and 10.37±1.54 mm for large whole kola nut pods respectively. The average mass, volume and density of whole kola nut pods were 0.154±0.071 kg, 1.475±6.071x10-4m3, and 471.374±98.756 kg/m3, respectively.

The force required to break kola nut pods along its lateral axis was 2691.27±1030.74 N and 421.66±363.97 N for longitudinal axis. The energy needed to break a pod along its lateral axis was 19.78±10.27 J; and 7.617±2.798 J for longitudinal axis. The lateral force and energy were more in both cases; hence it will be better to break the pod along its longitudinal axis.

A pod breaking machine with optimum machine capacity of 501.081 kg/h, maximum machine efficiency of 80.94 % and total cost of N40, 200 k was developed.

Keywords: kola nut pods, machine capacity, machine efficiency, mechanical properties, kola nut pod breaking machine

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1 Introduction

Kola nut is chewed in many West African cultures, either individually or in group settings and is often used ceremonially especially during wedding. Among the various non–wood forest products in the sub-region, *Cola nitida* and *Cola acuminata* are extensively cultivated because of the immerse contribution to the social, economic and cultural life of the people in West and Central Africa. The extraction process is largely non–mechanized. The kernel with the membrane covering it is slit open by holding it on the palm and cut through by the use of machete along the natural line of cleavage of the pod. This process is arduous and risky. The experience of the farmer in processing the pods suggests that pod breaking and separation of kola nuts from the husks are difficult task because breaking of pod is slow, time consuming and labor intensive. The pods are slit open one after the other by the farmer under the kola nut tree. The kola-in-pod is brittle and a large part is bruised thereby reducing the market value of the kola nut. Apart from the large labor requirement and time consumed during the operation the cutlass can damage the beans, resulting in reduction of market value for the beans. This makes some of the beans to be unsuitable for fermentation causing losses (Bamgboye, 2003). Shape, size, volume, surface area, density, porosity, color, and appearance are some of the physical characteristics which are important in many of the problem associated with the design of a specific machine or analysis of the behavior of a material handling operations. The structure of the pod is believed to be important in relation to the pods breaking behavior, just like it was explained for cocoa structure in relation to its pod breaking behavior

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(Maduako and Faborode, 1990). Hence it is considered essential to first characterize the pods breaking behavior through impact and compression tests on kola nut pods (ASAE Standards, 1990), for meaningful design and fabrication of the machine for processing and kernel extraction from the pod. Previous research using other crops, such as cashew nut (Oloso and Clarke, 1993), Macadamia nuts (Wang and Mai, 1995), and cocoa pod (Maduako and Faborode, 1994, Bamgboye and Odima-Ojoh, 2004) indicated that significant information on the fracture of a biomaterial may be obtained by subjecting it to quasi-static compressive and impact loading.

Olusoji (1980) developed a cocoa bean extractor that works on the principle of impact from hammer on the pod positioned on a centering table. Adewumi and Fatusin (2006) followed a similar approach in developing a manually operated cocoa pod breaker for seed extraction. The objectives of this study are: 1) to design and fabricate a kola nut pod breaking machine; and 2) performance evaluation of kola nut pods breaking machine.

2 Materials and methods

2.1 Moisture content

The moisture content of whole kola nut pods harvested from the farm were dried for a period of five to six days using oven conventional current at a temperature of 105 ^{o}C, during which the pods were checked for weight loss every 24 hour interval until constant weight was obtained.

2.2 Dimensions of the whole pods

The length, breadth, width of whole kola nut pods and thickness of the pod husks were determined using venier caliper. The values were determined using kola nut pods harvested fresh at Apomu in Osun State, using fifty of these pods. The kola nut pods were sub-divided into 16 large sized pods, 15 medium sized pod, and 19 small sized kola nut pods.

2.3 Mass, volume, density of whole kola nut pods

The masses of the 50 pods were determined using a weighing balance. The volumes of the pods were determined from the length, breadth and width values. The densities were also determined from these values. The weighing balance is as shown in Figure 1.

Figure 1 Weighing balance for mass determination

2.4 Compressive test

This test was conducted using 20 kola nut pods at the same moisture content wet basis with that of the physical properties that was carried out. The machine used to carry out this test is called testometric machine. The pods were divided into large and medium pods. The test was also conducted on longitudinal and lateral positioned pods. Five pods each were used for large and medium sized pods to determine its longitudinal and lateral axes. These are shown in Figures 2 and 3.

Figure 2 Longitudinally positioned compressive test on kola pods

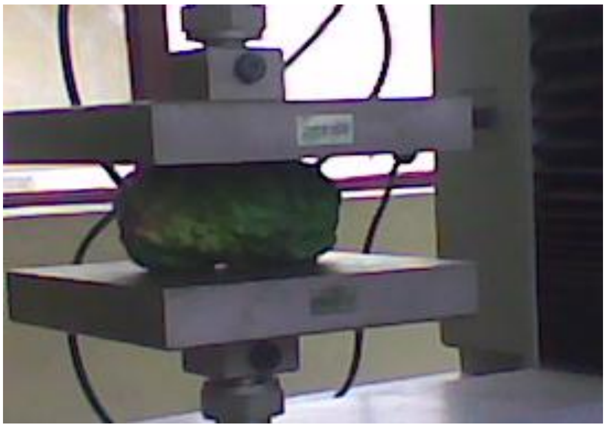

Figure 3 Laterally positioned compressive test on kola pods

2.5 Machine description

The machine consists of the frame, hopper, bearing and pulley, hammer and rope assembly, the electrical/electric motor connection and then the outlet. The hammer was rectangular in shape, 330 mm × 300 mm × 10 mm and the wooden plank was also rectangular with dimension 300 mm × 290 mm × 20 mm. The collar was made up of metal bars, separated at a distance that was equivalent to half of the diameter of the kola nut pods, (50.8 mm). The wooden plank was serrated so that it would rest on the metal bars keyed together. The shaft – rope assembly was rotated by a 2.238 kW, 1440 r/min electric motor. The machine is as shown in Figure 4.

Figure 4 Kola nut pods breaking machine

The wooden plank was screwed to mild steel, and the kola nut pod was impacted by the hammer. The hammer was attached to the shaft drum by the use of bull dog-hook which was screwed tight at the point of connection with the shaft and hammer. The rope was tied to the hammer and runs over the pulleys. It has adequate contact with the pulley. This allows easy sliding and pulling up of the hammer.

The machine is capable of breaking more than 4 kola nut pods at the hammers' maximum height of 550 mm. The rope tension was 171.675 N tensile stress and cross – sectional of 5.027 x 10^{-5} m^2 and 3414.90 kN/m^2 tensile stress. The rope mass and breaking loads are 7.06 kg/m and 1000 N. Speed of hammer was 5.65 m/sec. The total load on the pulley shaft was 1634.49 N and the power requirement of 1.498 kW. The shaft diameter of 25 mm was used by the machine.

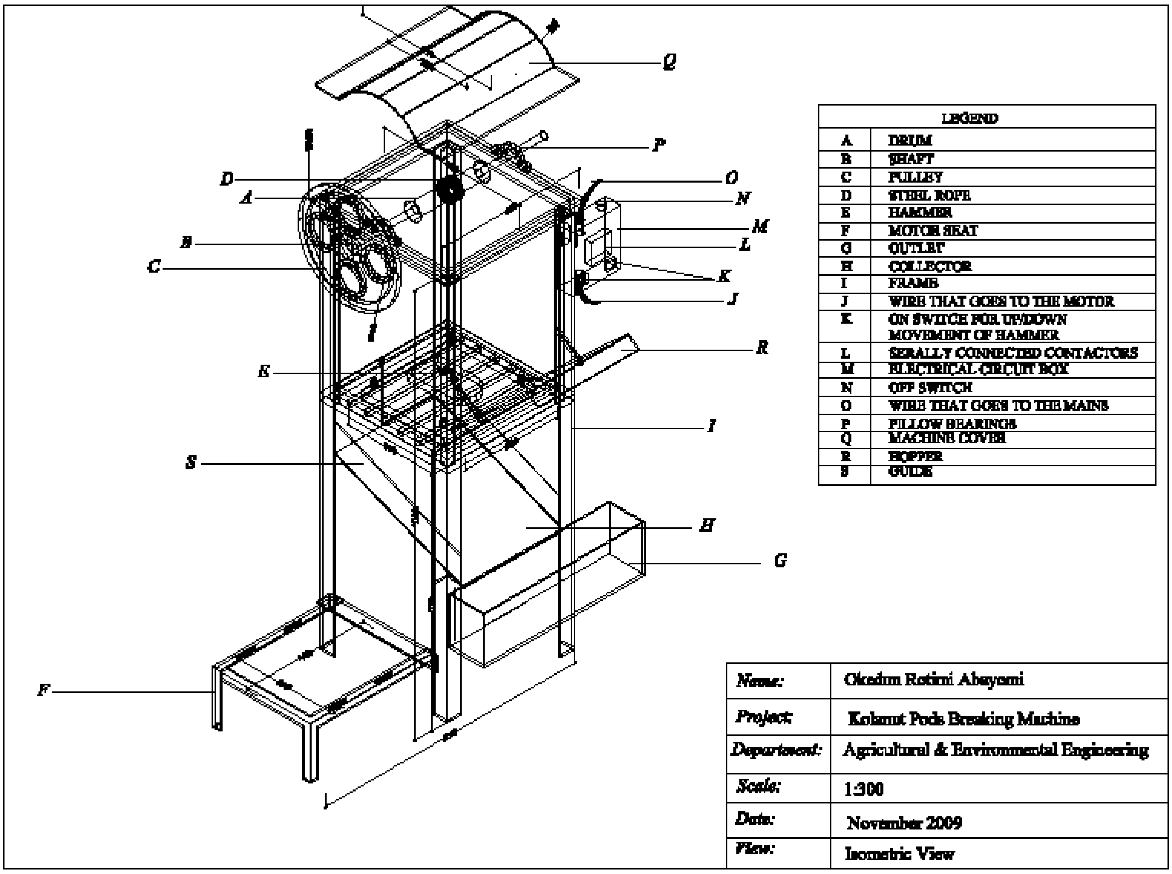

Figure 5 Diagram of designed kola nut pods breaking machine

2.6 Performance evaluation

Mature kola nut pods obtained from the farm were allowed to ferment for about five to six days after harvest. Forty fermented pods were grouped into one, two, three and four groups which were replicated four times for each group. They were weighed with a weighing balance before being loaded into the machine manually. Timing of test was achieved with the use of stopwatch in seconds. It should be noted that more than one hit by the hammer was required to be sufficient for breaking of more than one pod. The pods were loaded into the breaking chamber and the hammer released. The cotyledon was examined and classified into crushed and uncrushed. The parameters put into consideration are number of hit by the hammer, time required to break the pods, machine capacity, and efficiency of the machine.

The machine capacity (C) in kg/h, and the efficiency (F) were determined using the equation below according to Adewumi (2000).

$$C = M_P/T_B \quad (1)$$

$$F = M_U / M_P \times 100 \quad (2)$$

Where

C = machine capacity, kg/hr

T_B = time required to break pods, hr

M_U = mass of the uncrushed kola nuts, kg

M_P = mass of kola nut pods, kg

F = frequency of the machine, %

The speed of the machine used for this test was constant at 308.57 rev/min. The force impacted on each kola nut pod was 171.92 N from the hammer. The average moisture content of the kola nut pods for evaluation for various parameters was determined using the American Society of Agricultural Engineers, ASAE, 1990 (Now ASABE) standard base on initial and final weight of the whole pods.

The cost of production of the machine was estimated using available cost of materials as at the time of construction of the machine.

3 Results and discussion

3.1 Physical properties

The moisture content at which the physical and mechanical tests were carried out was 68.87% wet basis. The summary of the results for the physical properties are shown in Table 1.

Table 1 Physical properties of whole kola nut pods at 68.87% moisture content (wet basis)

Units	Dimensions	Sizes		
		Large	Medium	Small
mm	Length	108.54±7.79	89.52±5.52	64.26±11.42
Mm	Breadth	60.60±13.31	55.19±10.55	45.67±7.58
Mm	Width	46.97±10.23	43.75±8.38	37.87±5.80
Mm	Thickness	10.37±1.54	7.66±3.41	7.18±2.09
kg	Mass	0.154±0.071	0.115±0.043	0.062±0.027
$m^3 \times 10^{-4}$	Volume	1.475±6.071	2.237±0.762	1.167±0.438
kg/m^3	Density	471.374±98.756	511.346±89.917	545.630±153.096

The average length, breadth, width and thickness of whole kola nut pods were 108.54±7.79 mm, 60.60±13.31 mm, 46.97±10.23 mm and 10.37±1.54 mm for whole kola nut pods. These values are essential for the design of the machine breaking chamber which was able to occupy five big pods more conveniently. It was observed that during pod breaking, the hammer hit the pods at the contours which results in deformation of the husk of the kola nut pods. Hence, the husk breaking at the contours is more important for the design in this work. It was observed that maturity of the seed is as well crucial in this work in that if the kola nut pod is not matured enough it gives more resistance to breaking and it could be more frustrating. Half of the breadth of the kola nut pods was used in design of the passage for the kola nuts after it has been broken by the hammer and the width was taken to be 38.10 mm.

The average mass, volume and density of whole kola nut pods were 0.154±0.071 kg, 1.475±6.071 x 10^{-4} m^3, and 471.374±98.756 kg/m^3, for whole kola nut pods. These values are essential in determining some necessary capacities of a pod breaking machine. Density for instance is necessary for determining how much mass of the pods will occupy the breaking chamber per volume. Then, the stability or balance of a pod breaker during operation was affected by the mass of pods in the breaking chamber and hence the volume occupied by pods is very important in this area.

3.2 Machine performance

Figure 6 shows the relationship between time of pods breaking and both of capacity and efficiency of the machine. It was noticed that by increasing time of pod breaking from 1.300 to 3.608 sec., the machine capacity was increased from 412.615 to 501.081 with an average of 473.236 kg/hr. The average machine capacity decreased to 436.32 kg/hr at time of break of 3.608 sec. Also, machine efficiency increased from 75.67% to 80.94% at time of pod breaking from 1.30 to 2.035 sec. However, it decreased from 74.70% to 73.67% at the time of pods breaking from 2.874 to 3.608 sec.

The average force for whole pod along its lateral axis was 2691.271±1030.740 N, which was more than for longitudinal axis of 421.657±363.973 N. Also, the energy to break was more for the lateral axis, 19.782±10.270 J than for longitudinal axis, 7.617±10.270 J for compressive force and energy respectively. The machine design was based on the use of minimal (longitudinal axis) forces and energy so that fewer damages would be incurred during processing. The average results of the tests carried out were summarized in the Table 2. From the table, it was observed that the mass of uncrushed pods increased with time.

Table 2 Performance of kola nut pods breaking machine

No. of Pods	Time of break, secs.	Mass of pods, kg	No. of hammer drop on pod	Mass of uncrushed, kg	Machine capacity, kg/h	Machine efficiency, %	Mass of Waste, kg
1	1.300	0.149	3.00	0.113	412.616	75.67	0.036
2	2.035	0.283	3.00	0.229	501.081	80.94	0.0493
3	2.874	0.378	4.00	0.282	473.236	74.70	0.090
4	3.608	0.437	4.00	0.322	436.323	73.67	0.098
				Averages:	455.814	76.24	

The capacity of the machine was at a peak of 501.081 kg/hr and a minimum of 412.616 kg/hr as shown in Figure 6. The average capacity was 455.813 kg/hr, hence, the machine can successfully break 456 kola nut pods in one hour. This could be said to be good for the machine with an average efficiency of 76.24%. The efficiency increases with time and decreased after 2 minutes of operation as shown in Figure 7. It was also observed that the machine was most efficient when it was used to break two pods at a time and the machine capacity was also high at this stage, hence with this machine it is best to work with breaking two pods at once.

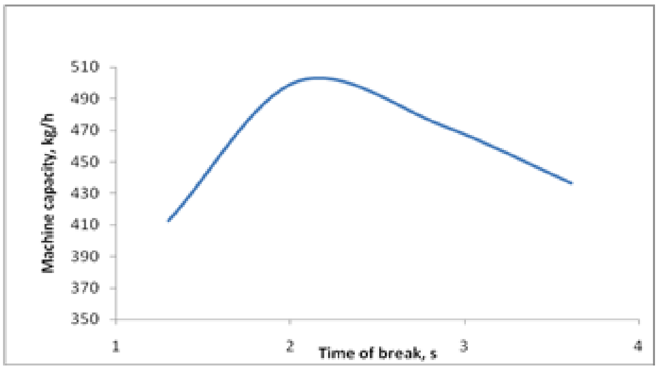

Figure 6 Relationship of machine capacity with time of pods nut breaking

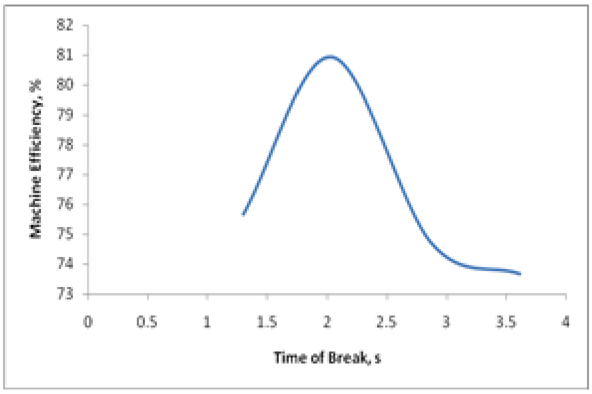

Figure 7 Relationship of machine efficiency with time of pods nut breaking

4 Conclusions

(1) The average moisture content of seventy kola nut pods used for the physical and mechanical properties was 68.87% wet basis. The average length, breadth, width and thickness were 108.54±7.79, 60.60±13.31, 46.97±10.23 and 10.37±1.54 mm for large whole kola nut pods respectively. The average mass, volume and density of whole kola nut pods were 0.154±0.071 kg, 1.475±6.071 x $10^{-4}m^3$, and 471.374±98.756 kg/m^3, respectively. The parameters are essential for detailed machine design.

(2) The average parameter for whole kola nut pod along its lateral axis was 2691.271±1030.740 N and for longitudinal axis was 421.657±363.973 N forces; energy to break for the lateral axis was 19.782±10.270 J for longitudinal axis, we have 7.617±2.798 J all for compressive force and energy for large pods. The lateral force and energy were more in both cases.

(3) The machine was designed, fabricated for the breaking of kola nut pods with a maximum efficiency of 80.94% at a speed of 308.57 r/min. The capacity of the machine was at 501.081 kg/hr at this same speed when two pods were broken.

(4) The total cost of the machine designed and fabricated was N40, 200 k.

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