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Original Research Article

Effect of rotor speeds of centrifugal palmnut cracker on the characteristics of the constituents of the crack mixture

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Separation of kernel and shell particles in a cracked mixture is a challenging process due to close relative sizes of the constituents. Samples of mixed varieties of ready- to-crack palm nuts at 7.82% mc (w. b) were cracked in with a centrifugal nutcracker at rotor speeds of 1760, 1891, 2068, 2175, 2250, 2450, 2650, 2800, 2962, 3150, 3300, and 3450 rpm with two replicates. The constituents of the cracked mixtures were separated manually, counted and weighed. The axial dimensions of the whole kernels obtained in each run were measured and used to determine the geometric mean diameter (GMD).The shell particles were subjected to particle size analysis and the results used to determine the geometric mean diameter and standard deviation of the shell particles. The results showed that the unit mass of shell particles decreased from 0.37 to 0.07g with increase in speed compared to kernels (0.65 to 0.80g). The GMD of the shell particles decreased from 11.09 to 5.72 mm compared to kernels (10.97 to 12.97 mm). The cracking efficiency increased from 37.5 to 98.0%, the percentage of broken kernels to total kernel product increased from zero to 19.2%. The findings showed that to limit the percentage of broken kernel to the total kernels production at 10%, the rotor speed was found to be at a range of 2800 to 3150 rpm, cracking efficiency 90.5 to 98%, unit mass of shell particles (0.08 to 0.11g) and GMD (6.34 to 7.73 mm)

Key words: Palm nuts, cracked mixtures, kernels and shell particles, geometric mean diameter.

INTRODUCTION

The palm fruit is one of the most important sources of oil for domestic and industrial purposes, exported to most countries in West Africa. As a drupe, it is made up of three major layers: an outer, epicarp; a fleshy mesocarp from which palm oil is extracted and a hard endocarp (shell), which constitutes the nut. The nut is a by-product after the extraction of palm oil from the fruit. The nuts are dried, cracked to release the oily kernels. The economic importance of palm kernel is indicated by its wide use as food, traditional medicine and in industries (Koya et al., 2004; FAO, 2004). Palm kernels are crushed in the local mills for the palm kernel oil and kernel cake. The kernel oil is used for the production of glycerin, margarine, edible oil, confectionery, candle, soap, oil paint and medicines. The kernel cake is an ingredient for livestock feeds in the livestock industries (Adebayo, 2004; Emeka and Olomu, 2007).The processing of palm nuts into kernel oil and cake involves the cracking of the nuts, separation of the kernels from the cracked mixture which is constituted of whole kernels, broken kernels, uncracked nuts and shell particles. The separation of the kernel from the shell particles is a very difficult process and it is an issue of great concern in the processing of palm nuts. The specific gravities of the kernels (1.10) and shells (1.30) are very close, and the wet method of separation is ineffective (Akubuo and Eje, 2002). In addition, the wet kernels must be sterilized against moulds and dried for 14–16h in silos to remove moisture picked up by the kernels. The dry separation methods include systems exploiting winnowing, reciprocating inclined plane, vibrating and reciprocating screens, rotating screens and indented cylinders. The efficiencies which have been reported in respect of these mechanical systems need considerable improvements.The physical characteristics of palm kernels and shell in the design and testing of a palm kernel and shell separator were determined by Akubuo and Eje (2002). The sphericity values for kernels and shell particles were 0.8 and 0.6 respectively. The angle of repose of about 38° for kernels and 47.9° for shells will aid in the design of hopper and spouts for a palm kernels and shells separator. The unit weights were 1.11g for palm kernel and 0.40g for shell particles. The geometric mean diameters were 12mm for palm kernels and 8.5mm for shell particles.

Gbadam et al. (2009) and others in their determination of some design parameter for palm nut crackers found that the production of whole and broken kernels, shell particle size of the shell after cracking are affected by nut moisture content, bulk density, feed rate, throughput capacity and the cracking speed. They concluded that both moisture content and rotor speed have significant effects on the crackability of the palm nut. A high level of fragmentation of the shell particles reduces the unit weight and geometric mean diameter of the shell particles. This work is to investigate the effect of the cracking speed on the characteristics of the constituents of the cracked mixture.

MATERIALS AND METHOD

Materials

Samples of ready- to- crack palm nuts of mixed varieties (*Dura*, *Tenera* and *Pisifera*) were purchased from the local market in Uyo, Akwa Ibom State. The nuts were cleaned manually by picking off foreign materials, broken and immature nuts. A sample of the nuts was used for moisture content determination by the oven dry method accordingly to ASAE standard (2000).

The nuts were cracked in a centrifugal nut cracker with a rotor of 200 mm diameter, ten (10) exit channels of 50x50 mm to propel the nuts against a 300 mm diameter cracker drum. A 4 kW electric motor running at a rated speed of 1450 rpm powered the nut cracker.

Experimental procedure

In each run, 200 nuts were weighed and fed into the rotating rotor through the conical shaped hopper. The nuts were cracked until no product was left in the cracking chamber. The rotor was run at 1760, 1891, 2068, 2175, 2250, 2450, 2650, 2800, 2962, 3150, 3300 and 3450 rpm based on the range of speeds carried out by other researchers.(Ndukwu and Aseegwu, 2010; Gbadam et al., 2009) The runs were replicated two (2) times at each speed. The cracked mixtures were collected and constituents separated manually, counted and weighed. The results were further tabulated for all speeds of the rotor.

Cracking Efficiency

The number of uncracked nuts was used to determine the cracking efficiency at each run

$$\text{Cracking efficiency} = \frac{\text{Number of cracked nuts}}{\text{Initial number of nuts}}$$

Unit mass of shell particles

The weight and number of the shell particles at each run were used to determine the average unit mass of the shell particles. The results obtained were tabulated for all the speeds.

Determination of geometric mean diameter (GMD) of palm kernels

The axial dimensions (major, intermediate and major diameters) of each whole kernel were measured and used to determine the geometric mean diameter as follows:

$$GMD = (abc)^{1/3} \qquad (1)$$

Where,
a = major diameter (mm)
b = intermediate diameter (mm)
c = minor diameter (mm).
The results obtained were tabulated for all the speeds.

Determination of geometric mean diameter (GMD) and standard deviation (GSD) of the shell particles

The shell particles in each run were subjected to particle size analysis. Seven (7) British Standard (B.S) sieves of sizes 19, 14, 9.5, 6.3, 4.75, 2.36, 1.18mm apertures and pan were arranged with the largest on top. The weighed shell particles were placed on the top sieve and shaken for 10minutes. The weights of the shell particles retained on each sieve were used to determine the geometric mean diameter and standard deviation of the shell particles by the Logarithmic Normal Distribution Parameters formula(ASAE Standard, 2000) shown below:

$$GMD_s = \log^{-1}\left[\frac{\Sigma(W_i \log d_i)}{\Sigma W_i}\right] \qquad (2)$$

$$GSD_s = \log^{-1}\left[\frac{\Sigma W_i(\log d_i - \log GMD_s)^2}{\Sigma W_i}\right]^{1/2} \qquad (3)$$

Where:
W_i is the weight of sample on each sieve (g)

Table 1: Average Weight Analysis of Palm Nuts, Kernels and Shells Before and After Cracking

S/N	Rotor Speed (rpm)	No. of Nuts	Average Initial weight of Nuts (gram)	Average Weight of Cracked mixture (gram)	Constituents of Cracked Mixture			
					Average Weight of Uncracked Nuts (gram)	Average Weight of Whole Kernels (gram)	Average Weight of Broken Kernels (gram)	Average weight of shell particles (gram)
1	1760	200	721.9	702.0	388.0	76.8	0.85	236.6
2	1891	200	693.1	663.5	259.1.	105.9	0.6	298.0
3	2068	200	670.1	609.8	173.9	117.2	0.0	318.8
4	2175	200	774.2	723.0	139.0	136.9	0.4	446.7
5	2250	200	829.5	791.2	201.5	159.8	1.2	428.5
6	2450	200	780.8	728.5	125.3	165.1	1.3	437.0
7	2650	200	757.5	734.5	78.6	181.6	3.25	481.3
8	2800	200	818.3	760.8	49.6	187.5	6.1	513.8
9	2962	200	606.5	590.2	29.0	146.5	12.8	416.1
10	3150	200	649.0	626.5	4.9	153.1	12.25	456.3
11	3300	200	701.0	679.9	11.2	154.1	27.3	487.3
12	3450	200	642.5	612.0	4.3	127.2	30.3	452.4

Table 2. Effect of Rotor Speed on Unit Mass of Kernel and Shell Particles

S/N	Rotor Speed (rpm)	Unit mass of whole kernel (g)	Unit mass of shell particles (g)
1	1760	0.65	0.37
2	1891	0.74	0.32
3	2068	0.76	0.24
4	2175	0.87	0.24
5	2250	0.99	0.26
6	2450	0.93	0.22
7	2650	0.94	0.19
8	2800	0.96	0.11
9	2962	0.77	0.12
10	3150	0.83	0.08
11	3300	0.90	0.08
12	3450	0.80	0.07

d_i is the diameter of opening of each sieve $(d_r x d_p)^{1/2}$ (mm).

d_r is the size of sieve on which particles are retained (mm).

d_p is the size of sieve through which particles will pass (mm).

The results obtained were tabulated for all the speeds.

RESULTS AND DISCUSSION

Moisture content

The average moisture content (% w.b) of the nut samples was found to be 7.82% (w.b).

Weights of the constituents of cracked mixtures

Table 1 shows the rotor speed, the number of nuts, the average initial weight of the nuts, the average weight of the cracked mixture and the average weight of the constituents of the cracked mixtures. The average weight of the uncracked nuts decreased from 388 to 4.3 g with increase in speed, showing the effect of the speed on the crackability of the palm nuts. The average weight of whole kernels increased from 76.8 to 187.5 g with increase in speed to 2800 rpm, and decreases thereafter with further increase in speed. The average weight of the broken kernels increased from 0.0 to 30.3 g with increase in speed. At high speed, more kernels are broken after cracking.

Table 2 shows the unit mass of whole kernel and shell particles. The unit mass of the kernels obtained from the

Table 3. The Rotor Speed and the geometric mean diameter of kernels and shell particles Values in (parentheses) represent standard deviation

S/N	Rotor Speed (rpm)	Cracking Efficiency (%)	% of Broken kernel to total kernel production	Kernel	Shell
				GMD (mm)	GMD (mm)
1	1760	37.5	1.1	11.29 (1.30)	11.09 (1.47)
2	1891	58.8	0.6	11.75 (1.35)	10.33 (1.49)
3	2068	68.0	0.0	10.97 (1.50)	9.41 (1.56)
4	2175	80.5	0.3	10.98 (1.40)	9.57 (1.54)
5	2250	70.8	0.7	11.37 (1.41)	9.45 (1.55)
6	2450	76.5	0.7	11.64 (1.43)	8.72 (1.57)
7	2650	86.8	1.8	11.76 (1.34)	8.31 (1.60)
8	2800	90.5	3.3	11.14 (1.53)	7.73 (1.61)
9	2962	90.5	9.0	12.19 (1.54)	6.61 (1.64)
10	3150	98.0	8.0	11.05 (1.29)	6.34 (1.67)
11	3300	97.0	15.1	11.35 (1.46)	5.97 (1.67)
12	3450	98.0	19.2	11.38 (1.39)	5.72 (1.70)

samples was between 0.65 to 0.99g while that of the shell particles decreased from 0.37 to 0.07g with increase in speed from 1760 to 3450 rpm. The unit mass of the shell particles is less than one-fifth that of the whole kernel from 2650 to 3450 rpm. The values are less than the 0.40 g obtained by Akubuo and Eje (2002) which shows the effect of the speed. The unit mass shows further fragmentation of shell particles relative to the kernels with increase in speed.

Table 3 shows the cracking efficiency (%), the percentage of the broken kernel to total kernel production, the geometric mean diameters of the kernel and shell particles. The cracking efficiency increased from 37.5 to 98% with increase in speed. The efficiency was found to be over 90% at a speed range between 2800-3450 rpm. At this speed range, the percentage of the broken kernel to total kernel production increased from 3.3 to 19.2% and the percentages greater than 10% at 3300 and 3450 rpm. At above 10 %, the quality of kernel production is low and attracts a low commercial value.

The geometric mean diameter (GMD) of the kernels was between 10.97 to 12.19 mm and definitely not affected by the rotor speed. Meanwhile that of the shell particles decreased from 11.09 to 5.72 mm over the speed range studied. The geometric mean diameter values of the kernels and shell particles are shown to be significantly different (probability p=0.05). At 3300 and 3450 rpm cracking speed, the GMD of the shell particles is about half of that of the kernel. The geometric mean diameter values show further fragmentation of the shell particles relative to the kernel size with increase in cracking speed.

However, to maintain a maximum of 10% of broken kernels to total kernel production and obtain high levels of fragmentation of the shell particles, the rotor speed is to be run between 2800 and 3150 rpm in confirmation with the findings by Ndukwu and Asoegwu (2010),that kernel breakage increased with cracking speed.

CONCLUSION

The results show that rotor speed affects the production of the whole kernel, broken kernel, and the size of shell particles. The results show a minimum of 90% cracking efficiency at rotor speed from 2800 rpm to 3150 rpm, and the percentage of broken kernels to total kernel production is less than 10%.

The unit mass of the shell particles is found to be one-eighth the unit mass of the whole kernel at the same speed range. The shell particle size expressed in term of the geometric mean diameter was found to be between 7.73 to 6.34 mm meanwhile that of the kernel ranged from 11.05 to 12.19 mm, which is comparably higher than the geometric mean diameter of shell particles at these speeds.

For 90% whole kernel production above, tolerable percentage of broken kernel, and smaller shell particles fragmentation relative to kernel, the rotor speed was found to be between 2800 to 3150 rpm. The increase in rotor speed has affected the production of whole kernels, broken kernels and fragmentation of shell particles. However to maintain the percentage of broken kernels to total kernel production at 10%, the rotor speed of the centrifugal nut cracker should be in the range of 2800 to 3150 rpm. This could enhance easy separation of the kernel and shell particles of the cracked mixture.

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