EFFECT OF MOISTURE CONTENT ON PALM NUT SHELL FRAGMENTATION FOR EFFECTIVE SEPARATION OF KERNEL

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ABSTRACT: *The search to accomplish effective separation of kernels from cracked nut mixture necessitated this work. In this study, nuts of bone-dry mass were soaked in water at room temperature and then subjected to cracking at 3-hourly intervals. The shell fragments and kernels obtained were further subjected to impact in order to examine the cycles of impact that would produce low % split kernels and high % shell fragments that could be sieved out while retaining on the sieve a high % kernels. Result revealed that at moisture content of 8.31% wb, impact energy of 0.4 J, impact speed of 25.32 m/s and 2 – 3 impact cycles, an effective separation of kernel was possible through production of shell fragments sizes that was sieved out to leave behind high % of kernels.*

KEYWORDS: Moisture Content, Shell Fragment, Palm Nut, Whole Kernel, Impact Energy.

INTRODUCTION

Three major varieties of palm tree exist. These are the Dura, Tenera and Pisifera. The Dura is characterized with large nut, thin epicarp and shell thickness of 2 to 5 mm. The Pisifera is sometimes regarded as shell-less variety while the Tenera is a hybrid of Dura and Pisifera. The Tenera has medium size nuts, thick epicarp and shell thickness of 1.0 - 2.5 mm (The Tropical Agriculturalist, 1989; Stephen and Emmanuel, 2009). Palm nut consists of the shell and the kernel; and are of economic importance (Adebayo, 2004; Emeka and Olomu, 2007; Hartley, 1987). To obtain kernel, the nut has to be cracked to release it. The cracked nut mixture consists of whole/broken kernels, shell particles, un-cracked nuts, fine particles and dust. Some factors that might influence the cracking of palm nuts and separation of cracked mixture to obtain high percentage of whole kernels include: nut density, moisture content, mass, size, shape, impact velocity, energy, number of cycles of hammer impact, etc. Besides, a maximum impact velocity of 31.03 m/s is required by nuts to be cracked in a centrifugal nut cracker. These factors limit the existing devices and different separating methods (Koya and Faborode, 2006; Eric *et al.,* 2009 ; Antia and Aluyor, 2018). Various researchers have carried out works in an effort to enhance effective processing of nuts to obtain good marketable kernels for the production of high-quality oil and cake. The moisture content is one of the major physical properties that influences nut cracking (Eric *et al.,* 2009). Antia, Olosunde and Offiong (2014) found that the optimum moisture content of 11.2% is necessary to yield at least 84.2% of whole kernels after cracking and separation. Feizollah (2012) in his study observed that, as pits moisture content decreased to 18%, % fully cracked pits and impact energy increased. Antia and Obahiagbon (2017) reported that it is rare to have kernels with minor diameter of less than 4 mm; hence production of high % shell fragments that can pass through sieve of 4mm is of advantage as it would leave more whole kernel and less shell fragment for further separation to achieve high purity kernel (i.e. kernel with little presence of shell fragments.

Dehulling/cracking of seeds/ nuts might be enhanced by soaking the nuts or seeds in water (Shafaei and Masoumi, 2013a). For local mills involved in processing palm nuts from different sources, there is that possibility of cracking over-dried or under-dried nuts; and so might result in having more split kernels. These make separation and other proprietary devices inefficient. The cracking of palm nuts to release whole kernels for separation, from cracked nut mixture is therefore a challenging process that needs improvement. More work is needed to assist the operations, especially in large scale mills. Therefore, the thrust of this work was to examine the effect of moisture content on shell fragmentation for effective separation of kernel. This would aid in the conditioning of nuts for cracking to produce shell fragments sizes that would encourage high percentage of kernel separation when a well-designed separating system is employed.

LITERATURE/THEORETICAL UNDERPINNING

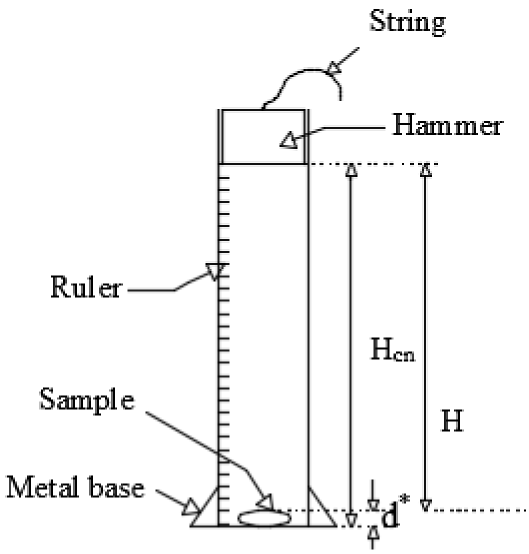

Figure 1: Sketch of Static Nut Cracker and Kernel/Shell Fragmentation Test-Rig.

When the mass of a hammer (M) falls through a height (H) on the sample of mass $\hat{m}$, the workdone due to gravity is given as:

$$P.E = MgH \quad (1)$$

Once the hammer strikes the sample, the potential energy (P.E) is converted to kinetic energy (K.E). Assume that there is no rebound of the hammer, then kinetic energy is given (Asoegwu, 1995; Antia, 2011, Esua *et al.*, 2015) as:

$$K.E = \frac{1}{2}\hat{m}v^2 \quad (2)$$

Where v = hammer velocity (m/s)

Equating Equation 1 and 2,

$$MgH = \frac{1}{2}\hat{m}v^2 \quad (3)$$

But from Figure 1,

$$H = H_{cn} - d^* \quad (4)$$

Putting Equation 4 into Equation 3, we have:

$$Mg\,(H_{cn} - d^*) = \frac{1}{2}\hat{m}v^2 \quad (5)$$

$$H_{cn} = \frac{(\frac{1}{2}\hat{m}v^2)}{M_{h2}\,g} + d^* \quad (6)$$

where

a) $\hat{m}$ could be replaced with M_n , M_k or M_s for nut mass, kernel mass and shell mass respectively.

b) H_{cn} could be replaced with H_n , H_k or H_s for hammer height measured from the base of static nut cracker for impact on nut, kernel and shell respectively.

c) d^* could be replaced with d_n , d_k or d_s for nut minor diameter, kernel minor diameter and shell thickness respectively.

d) M could be replaced with (i) M_{h1} for hammer mass used on nut, (ii) M_{h2} for hammer mass used on kernel and shell fragment.

e) g = acceleration due to gravity = 9.81 m/s^2

The average height (Ave. H) of hammer impact on the kernel and shell fragment could be expressed (Antia *et al.*, 2014) as :

$$\text{Ave. H} = \left[\frac{H_{spk} + H_{bs}}{2}\right] \quad (7)$$

METHODOLOGY

Palm nut of the Dura and Tenera varieties were purchased from an oil processing mill and dried to bone dry mass at 105^{0}C. Each variety was classified into three size ranges based on its minor axis(d_1), as: small size range($d_1 < 12\,mm$), medium size range ($12\text{ mm} \le d_1 < 17\,mm$) and large size range ($d_1 \ge 17$ mm). A preliminary study to determine the soaking hours required for water at room temperature to penetrate into the nuts per size range without soaking the kernel(s) was estimated by soaking 20 nuts of equally mixed variety of Tenera and Dura per size range per water vessel. At 1-hourly interval, exactly two nuts were picked per size range per vessel and cracked to examine visually the depth of water penetration through the shell thickness using magnifying lens. This experiment was carried out until the time required for water to penetrate completely through the shell thickness was observed per size range of the mixed nuts before the experiment was discontinued. These times obtained per size range were taken as the maximum soaking time to be used in the study of moisture content effect on shell fragmentation.

To determine the moisture content effect of on shell fragmentation that would enhance kernel separation from shell fragments; twenty nuts of mixed variety per size range were subjected to cracking using static nut cracker (Antia, 2011) at predetermined height drop using Equation 6 with hammer mass (M_{h1}) of 0.75 kg. Shell thickness of the cracked nut was measured using vernier calipers and recorded. The cracked mixture was then introduced into grizzly screen of aperture sizes: $P \leq 4$ mm, $P \leq 6$ mm, $P \leq 8$ mm, $P \leq 10$ mm, $P \leq 13$ mm and $P \leq 16$ mm ; and shaken for screening to obtain shell fragments of size ranges as: $0 < P \leq 4$ mm, $4 < P \leq 6$ mm, $6 < P \leq 8$ mm, $8 < P \leq 10$ mm, $10 < P \leq 13$ mm and $13 < P \leq 16$ mm. The mass of each shell fragment per size range of the shell fragment and their respective accompanied kernels were weighed and Equation 7 applied to obtain predetermined average height drop required for hitting the kernel and fragmenting the shell fragments; using static kernel/shell fragmentation Test rig with a hammer mass (M_{h2}) of 0.45 kg. The frequency or cycle of hammer (M_{h2}) impact that did not cause any objectionable damage to the kernel was used to further break the shell fragments other than $0 \leq P < 4$ mm as kernels are rare with minor axis, d_k = 4 mm (Antia and Obahiagbon, 2017). The re-fragmented shells were re-classified into six size ranges as $0 < P \leq 4$ mm, $4 < P \leq 6$ mm, $6 < P \leq 8$ mm, $8 < P \leq 10$ mm, $10 < P \leq 13$ mm and $13 < P \leq 16$ mm. The percentage shell fragmentation and kernel wholesomeness were calculated at time, T = 0 hour. The mean and standard deviation were also calculated at time, T = 0 hour through the aid of data acquisition template powered by Microsoft Excel. The same procedure was repeated for the rest of the nuts and the replicates using three vessels immersing twenty nuts of mixed variety per size range per water vessel. At soaking time, T = 3 hours, the nuts were removed, mopped with paper towel to remove the surface moisture, reweighed and minor axial dimension retaken. The % moisture content was evaluated as described by ASAE, (2000) and Aviara *et al.,* (2005).

The procedure was repeated for other batches at 3 hourly soaking time, T = 6, 9, 12, 18 and 21 hours for small size range; T= 0, 3, 6, 9, 12, 15, 18, 21 and 24 hours for medium size range; and T = 0, 3, 6, 9, 12, 15, 18, 21, 24, 27 and 30 hours for large size range based on established soaking time carried out in the preliminary studies for these size ranges of nuts. The experimental design used to analyze the % moisture content effect on shell fragmentation and % kernel wholesomeness was Complete Randomized Design (CRD), i.e. one-way ANOVA. Multiple comparisons of moisture content at T = 0 hour (at bone dry mass) against other moisture contents on shell fragmentation and kernel wholesomeness obtained for the three size ranges at 3 hourly intervals were carried out using Dunnett t-test.

RESULTS/ FINDINGS

The data generated and computed for the three (3) size ranges of nuts with respect to the optimum moisture content, impact velocities, impact energies and cycles of impact that enhanced the production of high percentage of shell fragments capable of being sieved out in sieve aperture size of 4 mm to leave behind high percentage of whole kernel and few associated cracked nut mixture (shell and broken kernels) of different percentages on the 4 mm are presented in Table 1.

Table 1: Optimum of Moisture Content, Impact Velocity and Energy, Cycle of Impact, Percentages of Shell Fragment Sizes, Split Kernel and Whole Kernel.

Nut Size Range	Optimum Moisture content (% MC [wb])	Impact Velocity ($m.s^{-1}$)	Impact Energy (J)	% Shell Fragments Sieved out from Various Sieve Aperture Sizes						Cycle of Impact	% Kernel	
				≤ 4	≤ 6	≤ 8	≤ 10	≤ 13	≤ 16		Split	Whole
Small	9.15	26.72	0.17	100.00	0.00	0.00	0.00	0.00	0.00	2 - 3	0.5	99.5
Medium	8.46	24.31	0.36	78.00	6.95	1.50	2.90	10.65	0.00	2 - 3	15.0	85.0
Large	7.33	24.93	0.66	50.53	10.85	12.60	13.62	12.40	0.00	2	10.0	90.0
Bulk	8.31 (0.93)	25.32 (1.25)	0.40 (0.25)	76.18	5.93	4.70	5.51	7.68	0.00	2 - 3	8.5	91.5

Values in brackets are standard deviations

In a large-scale oil palm processing mill, it may be cumbersome or time wasting to classify the nuts into different size ranges. Hence, there is need to compute optimum values of the essential parameters to represent values for the bulk sample. This is presented also in Table 1.

The ANOVA result of the moisture content effect on shell fragmentation and kernel wholesomeness is presented in Table 2.

Table 2: ANOVA results on % moisture content effect on shell fragmentation and kernel wholesomeness.

Nut Size Range	Shell Fragmentation			Kernel Wholesomeness		
	F	R^2	Sig.	F	R^2	Sig.
Small	833.312	0.997	0.00	506.906	0.966	0.00
Medium	47.495	0.955	0.00	20.886	0.903	0.00
Large	13.518	0.860	0.00	43.930	0.952	0.00

Further analysis to compare the % shell fragmentation and % kernel wholesomeness of the un-soaked nuts at T = 0 hour, as a control, with soaked nuts at different moisture levels was achieved using Dunnett t-test and is presented in Table 3.

Table 3: Multiple comparisons of % moisture content at T= 0 hour against other % moisture contents using Dunnett t-test on shell fragmentation and kernel wholesomeness for the three size ranges.

Nut Size Range	% $MC_{T=T}$	% $MC_{T=0}$	Shell Fragmentation		Kernel Wholesomeness	
			M D	Sig.	M D	Sig.
Small Size	MC_3	MC_0	42.1200*	0.000	33.3333*	0.000
	MC_6	MC_0	51.0900*	0.000	76.6667*	0.000
	MC_9	MC_0	37.7633*	0.000	96.6667*	0.000
	MC_{12}	MC_0	45.2333*	0.000	76.6667*	0.000
	MC_{15}	MC_0	54.2900*	0.000	94.6667*	0.000
	MC_{18}	MC_0	54.2900*	0.000	96.6667*	0.000
	MC_{21}	MC_0	50.7000*	0.000	78.3333*	0.000

Medium Size	MC_3	MC_0	6.8667	0.548	-0.6667	1.000
	MC_6	MC_0	13.6667*	0.042	20.0000*	0.017
	MC_9	MC_0	24.3500*	0.000	40.0000*	0.000
	MC_{12}	MC_0	38.8333*	0.000	20.0000*	0.017
	MC_{15}	MC_0	44.6333*	0.000	40.0000*	0.000
	MC_{18}	MC_0	57.8667*	0.000	50.0000*	0.000
	MC_{21}	MC_0	61.8667*	0.000	40.0000*	0.000
	MC_{24}	MC_0	40.3667*	0.000	40.0000*	0.000
Large Size	MC_3	MC_0	-6.1633	0.908	10.0000	0.480
	MC_6	MC_0	-9.6600	0.542	0.00000	1.000
	MC_9	MC_0	-8.1600	0.715	0.00000	1.000
	MC_{12}	MC_0	-9.1633	0.599	10.0000	0.480
	MC_{15}	MC_0	-9.0967	0.607	20.0000*	0.020
	MC_{18}	MC_0	0.8467	1.000	20.0000*	0.020
	MC_{21}	MC_0	10.8400	0.417	30.0000*	0.000
	MC_{24}	MC_0	17.3400	0.060	60.0000*	0.000
	MC_{27}	MC_0	25.8433*	0.002	70.0000*	0.000
	MC_{30}	MC_0	34.8900*	0.000	70.0000*	0.000

DISCUSSION

From Table 1, an average optimum moisture content of 8.31%, impact velocity of 25.32 $m.s^{-1}$ and 2 – 3 cycles of impact energy of 0.4 J would be required to further break shell fragments to yield about 76.18% by weight of shell fragments that could pass through 4 mm sieve and retaining on the sieve 91.5% of whole kernels with possible 8.5% split kernels. It is necessary to note that kernel of size less 4 mm is rare, hence advantageous to produce shell fragment sizes that can pass through 4 mm sieve aperture size (Antia *et al.*, 2017). The obtained cracked mixture after sieving from 4 mm sieve could possibly be subjected to appropriate technique of separation to achieve kernels of high purity (i.e. kernels with little percentage of shell fragments).

The ANOVA results of % moisture content effect on shell fragmentation and kernel wholesomeness from Table 2 showed that there were significant at 5% level of probability. P-values were less than 0.05 for all three the size ranges. R-squared values for % shell fragmentation were 0.997, 0.966 and 0.955 and that of % kernel wholesomeness were 0.903, 0.860 and 0.952 for small, medium and large size ranges respectively.

From Table 3, the results showed that for small size range the mean differences (MD) for all the pairs were significant at 5% level of probability for both % shell fragmentation and % kernel wholesomeness. For medium size range, all the pairs had significant mean difference with p-values < 0.05 except for MC_3 and MC_0 pair, where p (0.548) > [0.05] and p (1.00) > [0.05] for % shell fragmentation and kernel wholesomeness respectively. Their mean values were not statistically different from each other. For the large size range, only MC_{27} and MC_{30} had statistically significant mean difference when compared with MC_0.The rest of the pairs did not have any statistically significant difference in their mean values for the % shell fragmentation. A critical look at the multiple comparisons of MC_0 (i.e. moisture content at T

= 0 hour) for % kernel wholesomeness with other moisture levels revealed that MC_3, MC_6, MC_9 and MC_{12}, i.e. moisture content at T = 3, 6, 9 and 12 hours respectively, did not have any statistically significant MD, since their p-values were greater than 0.05. But the rest had statistically significant difference in their mean values. This generally implies that the shell fragmentation as well as the retention of kernel wholesomeness following cracking is dependent on the nut/shell moisture level.

Implication to Research and Practices

The application of impact velocity of 25.32 $m.s^{-1}$, impact energy of 0.4 J and 2 - 3 cycles of impact on cracked nut mixture having shell moisture content of 8.31% wb; produced high percentage of shell fragments that passed through 4 mm sieve aperture size while retaining on the sieve a high percentage of whole kernel accompanying a very small percentage of shell fragments and split kernel for further separation technique to obtain kernels of high purity. More so, this information could be employed in the design of palm nut cracking and separating system.

CONCLUSION

Average optimum parameters such as moisture level of 8.31%, 25.32 $m.s^{-1}$ velocity of impact, 2 – 3 cycles of impact and 0.4 J of impact energy are necessary to achieve a high degree of shell fragmentation that could possibly be separated to obtain kernels of high purity.

Future Research

The modeling of water absorption by dried palm nut soaked at room temperature is expected to be carried out.

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