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# INFLUENCE OF NUT CRACKING METHODS ON KERNEL QUALITY AND SEPARABILITY OF PRODUCT

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### ABSTRACT

In order to provide rational basis for design considerations to reduce kernel breakage in palm nut cracking using the conventional centrifugal nutcracker and enhance subsequent kernel and shell separation, comparison was made between the qualities of products from manually and mechanically cracked nuts. Furthermore, a 23 factorial experiment was conducted to determine the effects of the machine operational parameters and size of nut on nut cracking efficiency, quality of recovered kernels, and fragmentation of the nutshell. The nutcracker with a throughput capacity of 250 kg/h and a rotational of 1100 rpm gave a cracking efficiency of 97.2%, but kernel breakage was up to 9.7%; however, kernel breakage was 5.5% when the nutcracker was driven at a lower speed of 800 rpm and unbroken nuts were recycled. In contrast, cracking the nuts manually yielded 100% cracking efficiency and 2.0% kernel breakage, but the process was cumbersome and time consuming. In relation to the separation of the product, shell particles passing through a sieve with 10 mm aperture were 71.3% of the total shell produced using the nutcracker; compared with 58.3% from nuts broken manually.

**Keywords:** *Palm kernel, Nutshell, Nutcracker, Separation, Sieving, Palm nut.*

## 1. INTRODUCTION

The challenges of cracking the palm nut more effectively, while protecting the embedded kernel from being crushed has attracted some research attention (Manuwa, 1997; Obiakor and Babatunde, 1999; Koya and Faborode, 2005). The nutshell possesses high resistance to fracture, while the embedded kernel is friable. Therefore, the nuts are sufficiently dried to enable the kernel shrink away from the shell, to reduce the possibility of crushing the kernel during nut cracking process. At failure, the nut fractures in a catastrophic brittle manner with the shell breaking into pieces. Because the physical properties of the kernels and shells are close (Akubuo and Eje, 2002; Koya et al., 2004) the resulting mixture presents a difficult problem of separation. In addition, kernel breakage during nut cracking makes the separation more difficult and, the market value of the kernels is reduced. It is worthwhile therefore, to control the nut cracking process to enhance the separation of the mixture.

Existing methods employed in nut cracking are manual and the use of powered mechanical nutcrackers. In the manual method, the processor breaks the nuts, one at a time between two stones, and by

experience, judging the magnitude of force applied once or repeatedly. The impact is controlled to prevent kernel breakage. Although, a hand-held nutcracker is described in the literature (Meriam and Kraige, 1998) it is rarely employed in palm nut cracking. Using the hand-held nutcracker is equivalent to loading a nut to failure between two parallel plates, which in a previous work (Koya and Faborode, 2005) was shown to be approximately equivalent to breaking the nut without multiple impacts in a centrifugal nutcracker. However, manual methods are cumbersome and time consuming, but have the advantage that the separation of kernel from shell is done simultaneously.

On the other hand, mechanical nutcrackers are usually of the centrifugal type: the nuts are fed into a slot turning at a very high speed and are hurled against a cracking ring; or with other types, fed against impact beaters turning at high speed. Therefore, large quantities of nuts are processed at a time, but efficient separation techniques are required to retrieve the kernels. The nut experiences multiple impacts, bouncing on the cracking wall, and secondary collisions with the walls of the rotating channels, or with the beaters. In spite of the repetitive impacts, however, some of the nuts are discharged uncracked; while, some kernels from cracked nuts are crushed. It may be assumed that broken kernels result because the kernels were further impacted excessively after the nutshell had been broken. Furthermore, because the palm nut is non-homogeneous and non-isotropic, variations exist in the nuts of same grade; the force required to crack a nut also depends on its diameter and its orientation against the cracking wall (Manuwa, 1998; Koya and Faborode, 2005). It is therefore reasonable to anticipate some optimum operating conditions, with lower impacts (as obtainable in the manual method) where, recycling uncracked nuts in the machine, all the nuts may be broken with no kernel breakage. The most challenging process in kernel recovery, once the nuts are broken, is the separation of the kernel and shell mixture. Whilst, most separators are liquid based, requiring enormous energy in re-drying the product; attempts to separate the kernels from the shell without admission of liquid have not yielded satisfactory results (Olie and Tjeng, 1974; Hartley, 1977; Akubuo and Eje, 2002; Koya and Faborode, 2006). Sophisticated equipment consisting of hydro-cyclone, conveyors and bin dryers are also too expensive for most farmers who operate as clusters of small scale processors, but providing about 77% of total yearly production (Owolarafe et al., 2002). Evidently, most difficulties in the dry systems were experienced with kernels and shell particles of comparable size grade; but better efficiencies were anticipated with shell particles of uniform but distinct sizes from the kernels.

Consequently, the focus of this work was to investigate the benefits of low impact nut cracking (represented by the manual method) in terms of kernel quality and separation of product, in comparison with the use of the conventional powered nutcrackers. It was expected that such investigation would lead to the identification of necessary modifications in the design of the conventional powered nutcrackers.

2. MATERIALS AND METHODS

2.1. Sampling Technique

A local palm oil processing settlement in Ayekoka, South of Ile-Ife, Nigeria, was chosen for the purpose of the study. Only Dura variety of the oil palm was available on the farm. The farmers operate as clusters of processors, cracking the nuts in turns in the community based mechanical nutcracker; alternatively, the farmers break the nuts manually between two stones. The nuts were sufficiently dried but not graded before being cracked, using any of the two methods.

In course of the experiment, a measure of 150 kg of the dried palm nuts was procured. The exact moisture content of the nuts was later determined in the laboratory, using the oven method, drying at 130°C for 6 hours, as specified for oil-bearing seeds (ASAE, 1982). Furthermore, a representative sample of the nuts was passed through a set of sieves BS 410 (Endecotts Limited, London) with 25, 20, 14 and 10 mm apertures to grade the nuts, to provide a description of the size distribution.

2.2. Determination of Nut Cracking Efficiency, Product Quality and Distribution of Nutshell Particles

2.2.1. Process Equipment and Preliminary Experiment

The centrifugal nutcracker available at the cracking station was powered by a 5 hp Lister engine, with the provision for adjusting its mean speed. As a prelude to the main experiment, the exact operating speed of the nutcracker was measured using a hand-held electronic tachometer. The internal diameter of the cracking ring was measured with a vernier caliper. The nuts were gradually fed into the machine in 10 kg batches; and the feed rate was estimated, dividing by the average time taken. The product (kernel and shell mixture) for each experimental run of three replicates was analysed separately. The least speed at which nut cracking was feasible and the highest speed yielding reasonably low kernel breakage were noted. These speeds were designated as low and high speeds, respectively, in the subsequent main experiment.

2.2.2. Influence of Cracking Methods

(a) Manual Method

In the manual nut cracking, five of the skilled processors on the farm were randomly selected and each was commissioned to crack 5 kg of nuts. Although, the processor separated the whole kernels from the shells simultaneously, as in practice, the lot from each processor was kept separately for further analysis.

(b) Mechanical Method

Based on the results of the preliminary experiment, a 2<sup>3</sup> factorial experiment was designed to determine the effects of machine speed, nut size and the loading times on nut cracking efficiency and percentage kernel breakage.

The nutcracker was driven at 800 or 1100 rpm, which were respectively, the low and the high speeds. The nut sizes were those retained on the 14 and 20 mm apertures; while the two loading times referred to running the nuts through the machine at once, or twice (sorting and recycling the uncracked nuts only).

2.2.3. Performance Indices

The kernels were sorted from the shells. The weights of the whole and the broken kernels were determined, measuring on an electronic top balance (Mettler, PL 1200) to estimate the cracking efficiency and the percentage kernel breakage. The cracking efficiency  $\epsilon_c$  was computed using Eqn. 1.

$$\epsilon_c = \frac{N_b}{N_T} \times 100\% \tag{1}$$

where,  $N_b$  is the mass in kg of broken nuts; and  $N_T$  is the mass in kg of nuts fed into the machine.

The percentage kernel breakage  $\eta_K$  was defined as

$$\eta_K = \frac{K_b}{K_T} \times 100\% \tag{2}$$

where,  $K_b$  is the mass in kg of damaged kernels, and  $K_T$  is the mass in kg of all the kernels recovered from the nuts.

The percentage kernel recovery  $K_R$  was therefore defined as follows:

$$K_R = (100 - \eta_K) \tag{3}$$

The shell particles from each cracking method were graded using the set of sieves. This was to determine the difference in the shell particles size distribution compared with that of the kernels, in view of separating the mixture.

3. RESULTS AND DISCUSSION

The moisture content (percentage wet basis) of the nut at the time of the experiment was 13.4%. The size distribution of the nut is shown in Fig. 1, which shows the cumulative proportion of nuts retained on the sieves with 20, 14 and 10 mm apertures as 23, 97 and 100%, respectively. The result implies that the nuts may be divided into two grades, defined by those retained on the sieves with 20 and 14 or 10 mm apertures; but about 3% of the nuts (consisting of small-sized nuts) will be lost if the sieve with 14 mm aperture is used. The average feed rate was calculated to be 250 kg/h.

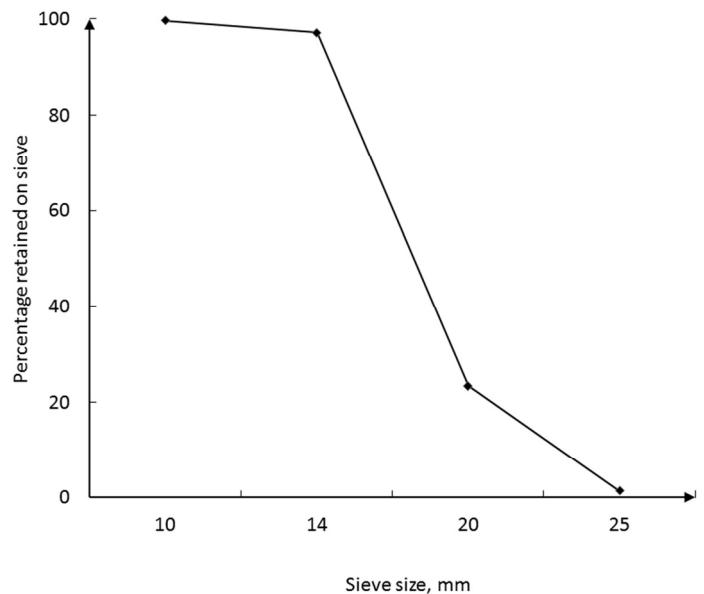


Fig. 1: Size Distribution of Nut Samples used in the Experiments

3.1. Effect of Nut Cracking Methods on Cracking Efficiency

The cracking efficiency and the percentage kernel breakage from the two cracking methods are shown in Table 1. The 100% cracking efficiency obtained in manual cracking is reasonable, since the processor ensures that all the nuts are broken; albeit, some kernels (2.0%) are also broken in the process. The mechanical nutcracker gave a cracking efficiency of 97.2%, but 9.7% of the kernels were broken, when driven at 1100 rpm. Although, this efficiency is lower than the 100% cracking efficiency obtained when the nutcracker was operated at the conventional speed of 1450 rpm, kernel breakage was reduced by about 52%. The percentage kernel recovery (90.3%) is also an improvement over the data reported by Obiakor and Babatunde (1999)

in respect of a similar nutcracker, with 95% cracking efficiency and 85% kernel recovery when driven at 1500 rpm.

Table 1: Efficiencies of Two Palm Nut Cracking Methods

Method of Nut Cracking	Cracking Efficiency, %	Kernel Breakage, %
Manual (between two stones)	100.0 (0.0)*	2.0 (0.0)
Centrifugal Nutcracker		
driven at:		
1450 rpm	100 (0.0)	20.0 (0.2)
1100 rpm	97.2 (0.2)	9.7(0.5)
800 rpm	89.4(1.5)	5.5(0.4)

\*Numbers in parentheses are the standard deviations.

However, operating the nutcracker at too low a speed (800 rpm and below) may not be beneficial, except the unbroken nuts are sorted out and re-introduced into the machine. It was observed that the unbroken nuts consisted of the small-sized nuts.

### 3.2. Effect of Nut Cracking Methods on Shell Fractions

The sieve analysis of shell particles obtained from the two nut cracking methods are shown in Fig. 2. From the result, mechanically cracked nuts yielded smaller shell fractions than the manually cracked nuts, and the difference, using paired t-test (Barnes, 1994) is significant at the 95% confidence level. Shell particles passing through the sieve with 10 mm aperture are 71.3% of the total shell produced using the nutcracker and 58.5% of shell from manually broken nuts. This result may be attributed to the fact that the nutcracker breaks the nut by impact, and with repeated impacts, the brittle nutshell is shattered into smaller fractions; albeit, with attendant kernel breakage, because the kernel is similarly affected. On the other hand, manually cracked nut is impacted skillfully by the processor until the nut breaks and without further impact on the nutshell once the kernel is extracted; thus, terminating the shell comminution process.

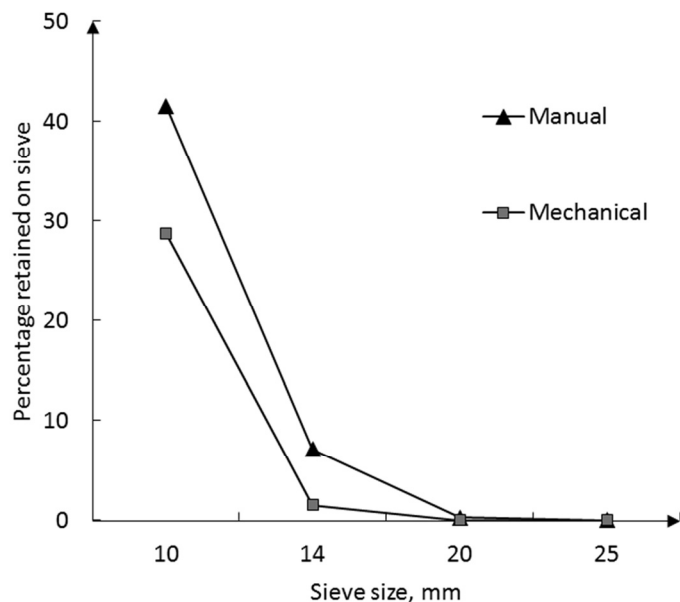


Fig. 2: Size Distribution of Shell Particles from Palm Nuts Cracked Manually and Mechanically

It is worthy of note that the least mean diameter of Dura kernels is more than 10 mm (Koya, 2004). Hence, the large percentage of shell particles smaller than the kernels suggests benefits in the use of sieves to pre-clean palm kernel and shell mixture when mechanical nutcracker is used. The remaining mixture may then be further separated by other methods.

### 3.3. Effects of Machine Operational Parameters on Product Quality

The result of the 2<sup>3</sup> factorial experiments on the effects of machine's rotational speed, nut size and the loading times on the quality of product from mechanically cracked nuts is shown in Table 2. The mean value of each experimental run was compared with the associated standard error to determine the bound of the statistic (Box et al., 1998). The effects of kernel size and machine, as well as kernel size and loading times have large interactions, so that the contributions of each pair are confounded statistically.

Table 2: Estimated Effects from 2<sup>3</sup> Factorial Design On Quality of Product From A Mechanical Nutcracker

Effect	Estimate ± Standard Error	
	Cracking Efficiency, %	Kernel Breakage, %
Average	95.5 ± 1.0	7.7 ± 0.1
Main effect:		
Kernel size, K	8.0 ± 1.9	5.6 ± 0.2
Speed, S	6.0 ± 1.9	4.3 ± 0.2
Number of runs, N	4.6 ± 1.9	0.4 ± 0.2
Two factors interactions:		
K x S	-6.8 ± 1.9	0.0 ± 0.2
K x N	-3.8 ± 1.9	-0.6 ± 0.2
S x N	-1.8 ± 1.9	0.0 ± 0.2
Three factors interaction:		
K x S x N	2.5 ± 1.9	-0.3 ± 0.2

Cracking efficiency increased up to 100% (p < 0.01) at 1100 rpm for both nut sizes; similarly, 100% cracking efficiency was obtained running the unbroken nuts through the machine while operating at 800 rpm. Kernel breakage increased by 5.6% (p < 0.05) when bigger nuts were fed into the machine compared with when the smaller nut were fed at the same speed, confirming the need to grade the nuts for cracking at different speeds. Operating the nutcracker at the 1100 rpm increased kernel breakage by 4.3% (p < 0.05) compared with cracking the same grade of nuts at 800 rpm. The foregoing observations are justified because the bigger nuts are subjected to higher impacts when the two grades are hurled at the same speed. When the nut is recycled at the lower speed, the nutshell fractures at lower impact; thus, reducing the incidence of kernel breakage; but the shell particles, being brittle, are further broken into smaller fractions. This development is beneficial because the finer shell particles will enhance the use of sieves in pre-cleaning the mixture.

Based on these results, therefore, the conventional mechanical nutcracker will give better performance in terms of cracking efficiency and kernel recovery, if it is operated at lower speed and unbroken nuts are recycled. Alternatively, a multistage nutcracker, equipped with twin cracking chamber in series, and driven at speeds lower than the operating speed of an equivalent conventional nutcracker should give similar result. The lower limit of the driving speed will be determined by the fracture resistance of the nutshell and the hardness of the cracking chamber.

### 4. CONCLUSION

The performances of manual and mechanical nut cracking methods were compared in the study. Operating the conventional centrifugal nutcracker at 1100 rpm gave minimum cracking efficiency of 97.2% at a higher throughput capacity; albeit, with higher kernel breakage, compared with breaking the nuts manually. Shell particles from the nutcracker were finer, enhancing pre-cleaning of the kernel and shell mixture.

Furthermore, the study showed that the undesirable kernel breakage, associated with the use of the conventional centrifugal nutcracker, can be reduced by driving the machine at lower speeds;

and recycling the unbroken nuts. Consequently, the study provides the basis for future modification of the conventional nutcracker as a multistage nutcracker, to reduce kernel breakage while enhancing subsequent separation of the resulting palm kernel and shell mixture.

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