Determination of Optimum Moisture Content of Palm Nut Cracking for Efficient Production of Whole Kernel

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ABSTRACT: After processing the palm fruit for oil, the nut is usually dried in order to loosen the kernel from the shell. The drying is necessary to enhance the release of whole kernel when the nut is cracked. A study was carried out to determine the optimum moisture content of nuts for high yield of whole kernels during cracking. Thirteen identical groups of fresh palm nuts with 240 nuts per group were subjected to oven drying at a temperature of 105 °C. Before starting, the initial mass of each nut was noted and at 2 h-intervals, a group was randomly selected and each of the 240 nuts cracked by impact after weighing for the determination of the nut moisture content. The nuts in the last group were cracked after a drying time of 26 h. The percentage of cracked nuts yielding whole kernels after impact cracking was used to determine the optimum moisture content the average value of which was 2.5% wet basis or 2.57% dry basis. At this moisture content the proportion of evaporable water retained in the intact nuts was estimated to be about of 11.2%. At the optimum moisture content, 84.2% of the cracked nuts yielded whole kernels. The optimum moisture content was obtained after a drying time of about 18 h.

KEYWORDS: optimum, moisture content, nut cracking, whole kernel

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I. INTRODUCTION

The varieties of oil palm tree grown in Nigeria include the Dura, the Tenera and the Pisifera. The mature ripe fruit consists of: an outer epicarp, a middle fibrous mesocarp from which oil is extracted and a hard breakable endocarp called shell which encloses the kernel. When the fruits are harvested and processed, one of the byproducts is the nut. The nuts are cracked to obtain kernels and shell fragments (Badmus, 2002). The kernels which contain 80% oil and 9% protein (FAO, 2009) are crushed for oil and cake. The oil is used for the production of edible oil, margarine, confectionary, soap, candle glycerin and ice cream. The cake is used for formulation of animal feeds. The shell fragments are used as fuels and for decoration of living apartments (FAO, 2009; Mahmud *et al.*, 2009).One of the major factors that affect the crackability of nut is the moisture content.

A study by Asoegwu (1995) on Conophor nuts revealed that the cracking energy increased with both nut mass and nut diameter but decreased with increase in shell moisture content. The moisture content of air dried palm nut used by Babatunde and Okoli (1998) in their investigation of the effect of nut sizes on speed needed for cracking palm nuts in centrifugal nut cracker was 7.19% dry basis. Akubuo and Eje (2002) used palm nuts having an average moisture content of 9.5 % wet basis in their work on palm kernel and shell separator. Palm nuts could be dried by indirect heat transfer method as in oven drying or by direct heat transfer method like in sun drying. The drying time and rate of drying affects the loosening kernel from the shell which enhances the release of the kernel when the nuts are subjected to appropriate impact energy (Okoli, 2003; Gbadam *et al.*, 2009). When nut moisture content is high, the kernel recovery after nut impact is low because most kernels adhere to the shells. The oil obtained from kernels at high moisture content may also quickly get rancid (FAO, 2009).

At very low moisture content, the possibility of producing split kernels following nut impact increases because the over dried kernels cannot withstand the stress during impact. It is therefore necessary that optimum moisture content of palm nuts for the efficient cracking be investigated. A study of the optimum drying time for sun-dried palm nuts, for efficient nut cracking was carried out by Okoli (2003) but the moisture content was not reported. The objective of this study was therefore to determine the optimum moisture content for the production of whole kernel from a palm nut cracked by impact in a static nut cracker.

II. MATERIALS AND METHOD

Fresh palm fruits of the Dura and the Tenera varieties were harvested and processed to obtain fresh palm nuts. The nuts were wiped dry with a clean cloth. A venier caliper was used to measure each nut minor diameter d_1. The measured nuts were then classified into 24 size ranges based on 1 mm intervals from $d_1 < 6$ mm to $d_1 \geq 29$ mm. Thirteen groups of nuts were used for the study. To obtain a group, 10 nuts each were randomly selected from each of the 24 classes of nuts. There were 240 nuts in a group. A total of 3120 nuts were used for the study. The initial weight of each nut was obtained using electronic weighing balance. The 13 groups of nuts were placed in an air oven at 105 °C (Deshipande *et al.*, 1993).

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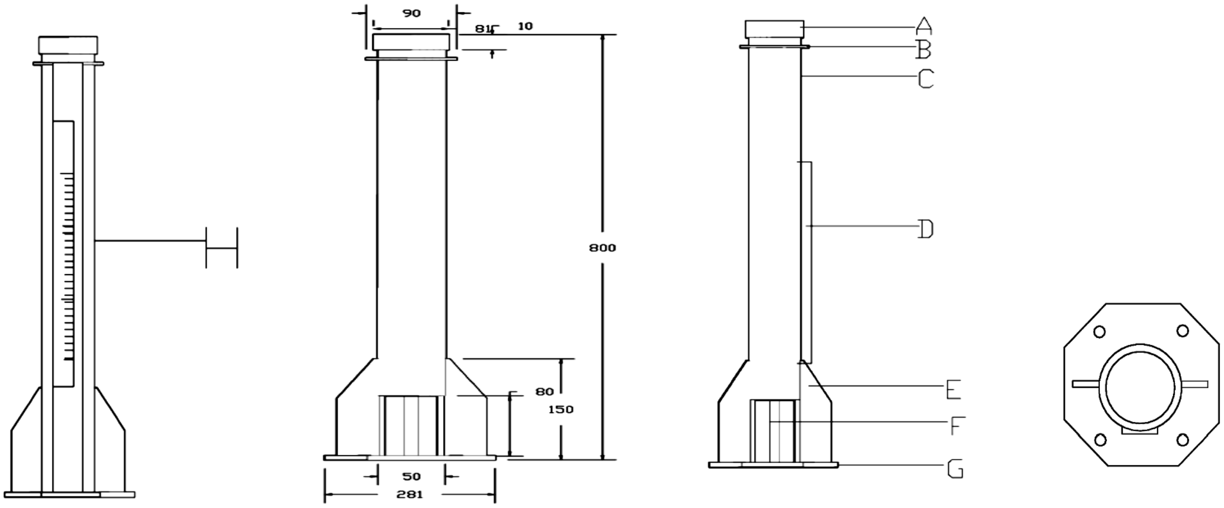

(a) Front view

(b) Rear view

(c) Plan view

Figure 1: Details of the static nut cracker.

Table 1: Legend for Figure 1.

Part	Description	Function
A	Hammer Inlet	Act as entrance to hammer
B	Casing Support	To enforce casing
C	Cylindrical pipe of 3 mm thick and inside diameter of 75 mm	Inside of pipe guide hammer falling to hit nut placed at the centre of base plate
I	Graduated Scale (0-600 mm)	To read off hammer height drop level
E	Base Support	To reinforce casing to base plate
F	Nut Inlet	For easy placement of nut on base plate
G	Base Plate	To withstand cracking force of hammer

At 2 h-intervals, a randomly selected group of nuts was removed and cooled in desiccators. The drying times in this study were 0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24 and 26 h. The weights of the cooled nuts per group of nuts per drying time were obtained. The moisture content and amount of lost moisture were determined from the weight lost (ASAE, 1983; Ajibola *et al*., 1990; Aviara *et al*, 2005). After the weighing, each of the cooled nuts was subjected to cracking using a static nut cracker (Figure 1) made of mild steel. For the impact cracking, a hammer of mass 1.25 kg was dropped in the cracker from pre-determined height of about 145 mm. The hammer was a cylindrical stainless steel having diameter of 74 mm and length of 50 mm.

The pre-determined height used corresponded to that obtained for effective cracking of dried palm nuts of various size ranges by Dienagha and Ibanichuka (1991). One nut at a time was placed at the centre of the base plate of the static nut cracker shown in Figure 1, whose legend is presented in Table 1. Thereafter the hammer was released and the nut cracked by the impact of the falling hammer. Visual observations of each nut after impact were carried out.

The number of nuts in the group that cracked with the release of whole kernel was noted and expressed in (KFC %) in eqn (1).

$$KFC\,(\%) = \frac{Number\ of\ Fully\ Cracked\ per\ group}{Total\ Number\ of\ Nuts\ per\ group} \qquad (1)$$

The evaporable water remaining in the nut was estimated from the following expression.

$$Q_{ei} = 100 - E_{H20} \qquad (2)$$

where Q_{ei} is the evaporable water remaining in the nut (%) and E_{H20} is the evaporable water lost from nut (%), estimated as follows:

$$E_{H2O} = \frac{M_O - M_{tn}}{M_O - M_{db}} \times 100 \qquad (3)$$

where, M_O is the initial mass, M_{tn} is mass of nut at a given drying time and M_{db} is the mass of nut dried to constant mass.

Equation (4) is obtained from eqns (2) and (3).

$$Q_{ei} = 100\left[1 - \left(\frac{M_o - M_{tn}}{M_o - M_{db}}\right)\right] \qquad (4)$$

The moisture content of the nut wet basis was estimated as presented in eqn (5) (ASAE,1983; Aseogwu,1995).

$$MC = \frac{M_i - M_f}{M_i} \times 100\% \qquad (5)$$

where M_i and M_f are the initial mass and final mass respectively.

The nut moisture content (%) dry basis obtained for various drying time were plotted against the corresponding percentage of fully cracked nuts (KFC %), that is the percentage of nuts that cracked with the release of whole kernels after impact. Optimal moisture content for efficient cracking was determined from the plot as the moisture content at which KFC % was maximum.

III. RESULTS AND DISCUSSION

It was observed as shown in Figure 2 that the rate of drying of nuts followed a typical trend of drying curve similar to that of Paul (1996).

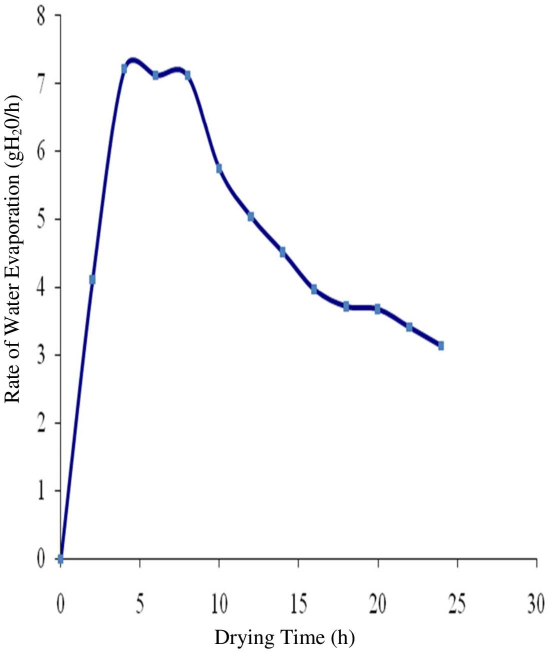

Figure 2: Average rate of drying of fresh palm nuts as a function of drying time.

The critical moisture content occurred at 4 h. A fairly constant drying rate was observed from 4 to 8 h followed by a falling rate up to the 24th hour after which the nuts attained constant weight. The average mass of the nut at constant weight i.e. the equilibrium mass was about 81.52% of the initial mass (M_O). The curve has 2 stages of falling rate occurring between 8 and 18h for first stage while 18 to 24 h is the second stage of which no more change in weight was observed at 24 h. The average conditions of the nuts during the drying process are summarized in Table2.

From Table 2, the percentage ranges of evaporable water at nut critical moisture content, constant drying rate and falling drying rate are: $0 < E_{H20} \leq 38.26\%$, $38.26\% < E_{H20} \leq 75.49\%$ and $75.49\% < E_{H20} \leq 100\%$, respectively. When the nuts were dried to constant weight (i.e. bone dry weight) at 24 h, the value of E_{H20} was 100%. Also, as the percentage of evaporable water in the nut decreased from 100% to 19.69% (i.e 17.52 to 4.18% wet basis or 21.24 to 4.36% dry basis), the whole kernel yield (%) in relation to nut moisture content (% w.b) increased up to 76.25% as shown in Figure 3.

Table 2: Average conditions of the nuts during the drying process.

	Drying time, Tn, (h)												
	0	2	4	6	8	10	12	14	16	18	20	22	24
Q_{ei} (%)	100.00	89.07	61.74	43.28	24.51	23.82	19.69	16.14	15.85	11.22	2.55	0.56	0.00
MC_{wb} (%)	17.52	16.41	11.78	8.60	5.20	4.95	4.18	3.79	3.55	2.50	0.60	0.13	0.00
MC_{db} (%)	21.24	19.64	13.36	9.41	5.48	5.20	4.36	3.94	3.68	2.57	0.61	0.13	0.00
E_{H20} (%)	0.00	10.93	38.26	56.72	75.49	76.18	80.31	83.86	84.15	88.78	97.45	99.44	100.00
Initial mass (g)	429.30	416.40	422.86	421.19	411.68	419.71	415.01	383.18	398.82	404.03	392.44	398.90	385.22
Mass at Tn (g)	429.30	408.18	394.08	378.52	378.52	354.41	354.60	320.10	335.52	337.52	319.14	324.6	310.00
Mass at constant weight (g)	354.08	341.18	347.64	345.97	336.46	344.49	339.79	307.96	323.60	328.81	317.22	323.68	310.00

A further decrease in the nut evaporable water retained in the nuts from 19.69 to 11.22% (corresponding to moisture content decrease from 4.18 to 2.5% wet basis or from 4.36 to 2.57% dry basis) resulted in gradual increase in the fraction of fully cracked nuts yielding whole kernels (KFC %) from 76.25% to a maximum of 84.20% and thereafter KFC decreased to 78.33% as the % evaporable water in nut decreases from 11.22% to 0% (i.e. moisture content decrease from 2.5% to 0% wet basis or from 2.57% to 0% dry basis). When the fraction of evaporable water in the intact nut was 11.22% (i.e. at nut moisture content of 2.5% wet basis or 2.57% dry basis) the KFC was 84.20% as shown in Figure 3.

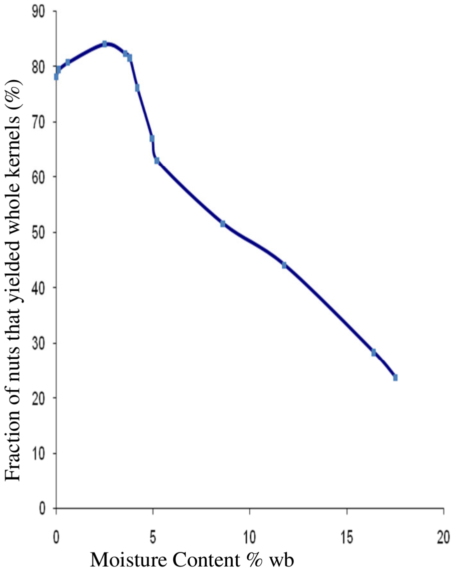

Figure 3: Whole-kernel yield (%) in relation to nut moisture content (% w.b).

However, KFC % has been found to be affected by the size and mass distribution of nuts cracked and, mass and height drop of hammer used for the impact (Babatunde and Okoli, 1988; Dienagha and Ibanichuka, 1991).

IV. CONCLUSION

A nut moisture content of 2.5% wet basis or 2.57% dry basis was determined to be the optimum for palm nut cracking for the highest yield of whole kernel. At that moisture content, the fraction of evaporable water retained in the intact nut was 11.2 % on the average and the proportion of nuts that yielded whole kernel was 84.20 %. For the oven drying method employed, the equilibrium weight of the nut was, on the average, 81.52 % of its initial weight. Practical implication is that at optimum nut moisture content, higher percentage of whole kernels could be achieved if appropriate nut impact energy is applied. Therefore, model for nut impact energy required for efficient production of whole kernels following nut cracking is suggested for further study to enhance effective design of an efficient nut cracker machine.

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