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Study of Moisture Content Dynamic of Fresh Palm Nuts during Drying

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ABSTRACT: *Nut drying as a unit operation is cost intensive and requires energy intensity to achieve moisture content that would enhance effective nut cracking to yield whole kernels. Small Scale farmers mostly in the rural areas primarily employ open air drying method; as they are handicap with capital, technique and skill involved in modern methods of drying and determination of desired end moisture content. To develop cheap and easy approach in estimating any desired end moisture content; this paper attempts to establish and utilize the relationship, if any between moisture content and the ratio of initial mass of fresh nuts at time zero (M_o) to time dependent mass of nuts at any time t (M_t) when subjected to drying. In this study, fresh palm nut where classifies into three size ranges based on their geometric mean diameter. Each size range was subjected to drying in hot air convection oven; and M_o/M_t ratio recorded at various drying times until bone dry mass was achieved. The results reveal that irrespective of the size ranges of nuts, the M_o/M_t ratio is approximately the same at each drying time interval. The determinant moisture content corresponding to each drying time is approximately the same irrespective of the nuts size ranges. The empirical equations developed can be used in predicting the desired end moisture content.*

KEYWORDS: *Fresh palm nuts, nut mass ratio, moisture content, drying.*

I. INTRODUCTION

Oil palm grows well in Africa, South Asia and America. In Nigeria, it is abundantly grown in Southern part and is mostly three varieties namely Dura, Tenera and Pisifera. The oil palm is straight branches trunk tree with leaves (frond) clustered at the top; and usually bear fruit. These fruits are oval in shape and have three major layers namely the outer epicarp, middle mesocarp; a breakable endocarp called shell. Palm oil is obtained from the fibrous mesocarp; while shell encloses the kernel(s) (Wood et a1., 1976; Hartley 1977). However, the shell thickness varies from 4mm to 8mm (Hartley, 1977, Purseglove, 1975; Zibokere, 1998; FAO, 2009). The oil palm generally has numerous importances. Its frond could be used in locally made basket, broom, etc; the oil from the mesocarp and kernel could be used for manufacturing edible oil, margarine, soap etc; the palm kernel cake is used mainly for livestock production (Turner and Gillbank, 1974; Vaughan, 1976; Elaine, 1968) and the broken shells could be used in decorating apartment premises, packing material in distillation columns for alcohol and as fuel (FIRRO, 1973; Koya et al., 2004)

It is worthy to note that the kernel of the oil palm fruit, the extraction of which is sole reason for cracking, is grown for food and contains 48percent of oil and 9 percent of protein. The kernels are obtained from oil palm fruits after separation, drying and cracking of the shells. The cracking of nut is basically carried out by manual or mechanical method (Badmus, 1991; Illechie et al., 2005; Manuwa 1997; Sangwichien et al., 2010). Which ever method is applied for cracking, one of the most important things is that kernel released after cracking needs to be whole in order to be marketable. The critical parameters for good marketable kernel quality are that split kernel and foreign matter (broken shell) should not exceed 6 and 4 percent respectively (Turner and Gillbank, 1974).

However, the release of whole kernel after cracking depends on factors such as the moisture content, shape and size of the nuts, operating conditions for cracking (Asoegwu,1995; Okoli, 2003; Olakanmi, 2004; Oke, 2007). The primary pre-requisite for cracking is the quantity of moisture content in the nut. The removal of liquid from solid by evaporation is referred to as drying. Industrially, drying is conducted by two basic methods viz; the indirect heat transfer method and the direct heat transfer method. Heat is supplied to the material to be dried by high frequency currents or by infrared light (ie.Dielectric drying and radiant heat or infrared drying, respectively). According to Planovsky and Nikolaev (1990) all dryers in which the heat is required for drying is transferred to the wet material by conduction through a solid impermeable wall are indirect dryers and drying often falls into this group, and are the simplest of the indirect dryers. They are used when direct contact of the wet material with the drying medium can be objectionable. Okoli (2003) studied the effect of drying time and temperature on cracking, and found that the cracking effect is at peak in the forth week of air drying of nuts at 94 percent with whole kernel contributing 86 percent. He concluded that the importance of the result lays in the fact that small-scale palm fruit processors can now for certain know how long they would air dry their nuts to obtain effective nut cracking.

By and large, since the tropics have dry and wet seasons, it therefore remains a problem to estimate effectively the open air drying time because in each season, the sun intensity changes on a daily basis; and especially in the wet season, the sun intensity changes with intermittent rain and in some days it rains throughout. Hence, effective open air drying time for fresh palm nuts is not likely to be generally the basis of weekly assessment especially in the wet season. This study aims at findings an effective way of estimating the desired end moisture content when fresh nuts are subjected to any method of drying. During open-air drying of nuts in the wet or dry season, it may be possible and more effective to determine when to stop drying of fresh nut by developing a practical empirical protocol anchored on the theory of drying.

II. THEORY

Drying agricultural and food materials generally involves simultaneous application of heat and removal of moisture (water) from the material. Thus in drying of fresh palm nuts, the following assumptions can be made

(1) Let M_o = Initial mass of nuts at time zero (gram)
M_t = Time dependent mass of nut at time t (gram)
t = Time (hr)
M_d = Bone dry mass of nut (gram)

(2) Fresh agricultural and food materials of initial mass M_o should have a certain percent of evaporable water that would be lost at a certain period.

(3) The bone dry mass of fresh nut M_d could therefore be expressed as a certain fraction (F) of initial mass of fresh nut

$$FM_O = M_d \tag{1}$$

Generally, moisture content (MC) wet basis (wb) $= \dfrac{\textit{Initial} \ \text{mass} \ \text{- Final} \ \text{mass}}{\text{initial} \ \text{mass}}$ (2)

$$MC\ (wb) = \left[\frac{\mathrm{M}_t}{\mathrm{M}_t - \mathrm{M}_d} \right] \times 100\ \% \tag{3}$$

where, M_t at time zero is equal to M_o

Moisture content (MC) dry basis (db) $= \dfrac{\textit{Initial} \ \text{mass} \ \text{- Final} \ \text{mass}}{\text{Final} \ \text{mass}}$ (4)

$$MC\ (db) = \left[\frac{\mathrm{M}_t - M_d}{\mathrm{M}_d} \right] \times 100\ \% \tag{5}$$

$$MC\ (wb) = \left[1 - \mathrm{F}\left(\frac{\mathrm{M}_O}{M_t} \right) \right] \times 100\ \% \tag{6}$$

Substitute equation 1 in equation 5 and rearrange

$$MC\ (db) = \left[\left(\frac{1}{F\left(\dfrac{M_O}{M_t} \right)} \right) - 1 \right] \times 100\ \% \tag{7}$$

III. MATERIALS AND METHOD

Fresh palm nuts of a mixture of Tenera, Pisifera and Dura varieties were obtained from local palm oil processing mill and were immediately mopped with wet clean cloth and thereafter wrapped in a water-proof polythene bag. The nuts were classified on the basis of geometric mean diameter (GMD) into three size- ranges as follows: small size: (GMD) < 13mm; medium size: 13mm $\leq$ GMD <20mm; large size: (GMD) $\geq$ 20mm. In each size range, 200 nuts were randomly picked and each nut labeled before its initial mass (M_o) was weighed using an electronic weighing balance. The weighed nuts in each size range were subjected to drying in a hot air convection oven operated at 105^{o}C. Hence, a total of 600 nuts were involved in the test conducted.

However, at four hourly intervals, each size – range of nuts was removed from the dryer, cooled in a desiccator for 30 minutes. Thereafter, each nut mass (M_t) of each size – range was determined, recorded and the M_o/M_t ratio calculated. The experiment was repeated until the mass of the palm nut was observed to have little or no change in mass i.e. at bone dry mass.

Three sets of experiments were carried out, hence a total of 1800 fresh palm nuts were used. The M_o/M_t ratio obtained at each time was recorded for all the three size ranges of nuts classified in each set and were computed. The values were then used in obtaining standardized values of M_t for time t = 0 up to the time when dry bone mass was achieved. The standardized values of M_t were used in computing the moisture content of nuts at each recorded experimental drying time interval. Statistical analysis based on standardized values was carried out in order to obtain the value of F from equation 6 vis-a-vis the empirical equations 8 and 9.

IV. RESULTS AND DISCUSSION

Table 1: M_o/M_t. ratio at 4 hourly interval of drying for fresh Oil Palm Nuts

	Average Values of M_o/M_t.			**Bulk average of M_o/M_t.**
	GMD<13mm	13mm≤GMD<20mm	GMD≥20mm	
0	1.000	1.000	1.000	**1.000**
4	1.067(0.050)	1.066(0.051)	1.065(0.05)	**1.066(0.050)**
8	1.135(0.041)	1.137(0.038)	1.136(0.040)	**1.136(0.040)**
12	1.144(0.022)	1.148(0.030)	1.146(0.027)	**1.146(0.018)**
16	1.169(0.031)	1.167(0.039)	1.169(0.032)	**1.168(0.034)**
20	1.213(0.032)	1.214(0.038)	1.215(0.029)	**1.214(0.033)**
24	**1.236(0.048)**	**1.240(0.039)**	**1.237(0.040)**	**1.238(0.041)**

Values in brackets are standard deviations

These values represent the M_o/M_t average values for nuts subjected to drying per size range. The result showed that for each size range the M_o/M_t could be taken as being approximately the same at each drying time interval. Moreover, the values of each averaged M_o/M_t per size range per drying time interval were further averaged to obtain M_o/M_t values for bulk nuts per drying interval. The corresponding values of MC (wb) were found to also be approximately the same for each size ranges per drying time interval as seen in Tables 2.

Table 2: Moisture content percentages at 4 - hourly interval of Drying time per M_o/M_t ratio for fresh palm nuts

Times(hr)	**Averaged Values of MC (Wb %)**			**Bulk Average**
	GMD<13mm	13<GMD<20mm	GMD≥20mm	**MC (wb %)**
0	19.11	19.35	19.16	**19.21**
4	13.69	14.04	13.92	**13.88**
8	8.20	8.38	8.17	**8.25**
12	7.47	7.42	7.36	**7.42**
16	5.44	5.88	5.50	**5.61**
20	1.88	2.10	1.78	**1.92**
24	**0**	**0**	**0**	**0**

The MC (wb %) for bulk nuts per drying time were also computed. Drying rate curved was obtained for each size range as seen in Figure 1.

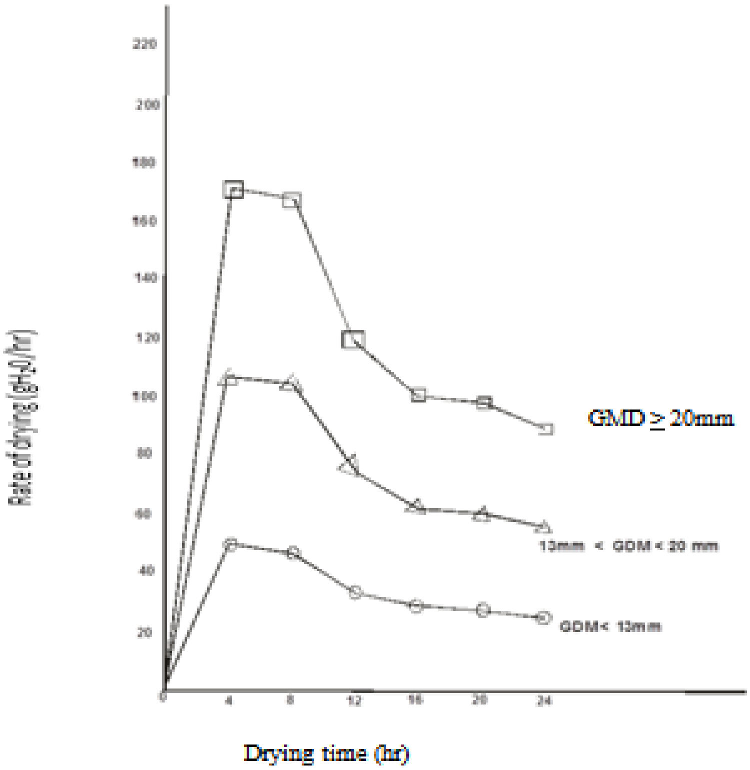

Figure 1: Rate of drying against drying of fresh oil palm nuts of classified size ranges

The drying curved resembled an ideal drying curve. This implies that the experiment values obtain can be used for analysis to obtain imperial relations for predicting moisture content percentages wet basis for fresh nuts subjected to any method of dying.

The experiment values of M_o/M_t in Table 3 shows that for a unit mass of fresh nut at dry bone mass, the initial mass of fresh nut at time zero is 1.238. Thus at each 4-hourly drying interval, standardized values could be obtained for M_t, MC (wb %) and MC (db %) as shown in Table 3.

Table 3: **Fresh Nut mass variations with respect to moisture content percentage at 4-hourly drying time intervals.**

Time (hr)	**Experimental values of $^{Mo}/_{Mt}$ for Bulk Nuts**	**Standardized values from Experimental values**			**Predicted values from empirical equations 6 and 7**	
		M_t(grams)	MC (wb%)	MC (db %)	MC (wb %)	**MC (db%)**
0	1.00	1.238	19.22	23.80	19.22	**23.80**
4	1.066	1.161	13.87	16.00	13.89	**16.14**
8	1.136	1.090	8.26	9.00	8.23	**8.96**
12	1.146	1.080	7.41	8.00	7.43	**8.03**
16	1.168	1.060	5.66	6.00	5.65	**5.99**
20	1.214	1.020	1.96	2.00	1.93	**1.98**
24	**1.238**	**1.00**	**0**	**0**	**0**	**0**

Least square statistical analysis was carried out based on equation 6 and Table 3 to obtain the value of F as 0.8078. These values was fitted into equation 6 to obtain equations 8 and 9 derived from basic theory of drying as highlighted in the theory section of the paper. The value of F is necessary to be obtained because the nut size varies but the value of F remains same irrespective of nut size. That is, the value of F is expected to be a constant for any particular fresh harvest material. The empirical equation for moisture content wet or dry basis is as follow:

(a) $$MC\ (wb\ \%) = 100 - 80.78\left(\frac{M_O}{M_t}\right) \quad (8)$$

(b) $$MC\ (db\ \%) = 123.8\left(\frac{1}{\left(\frac{M_O}{M_t}\right)}\right) - 100 \quad (9)$$

These equations were tested and analyzed to obtain a coefficient of determination r^2 of 0.974 and standard error of 1.96 percent. These values indicate that the equations are reliable and could be validly used.

V. CONCLUSION

The empirical equations 8 and 9 relating M_o/M_t and moisture content percent (wet basis or dry basis) are valid and reliable as standard error in using the equation is about two percent.

The bone dry mass of nut is (80.78 $\pm$ 3.98) percent of the initial mass of nuts obtained from freshly harvested and processed palm fruits.
An approximate moisture content of fresh nuts is (19.22 $\pm$ 3.80) percent wet basis or (23.78 $\pm$ 6.12) percent dry basis.

The equation 8 and 9 could be applied only to fresh nut subjected to drying by any method and given conditions.

Small-scale farmers that dry nuts in the sun whose temperature and intensity vary at all times and at all seasons could now know when to stop drying fresh nuts in order to obtain any desired end moisture content percent. This is done using equation 8 and 9 and substituting the M_o/M_t values obtained as drying progresses. When approximate desired end moisture content is obtained, the drying is discontinued.

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