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Determination of Drying Mass Constants of Selected Fruits Using Empirical Method

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ABSTRACT
Various techniques and methods have been used to dehydrate food material to a certain mass that correspond to a certain moisture content. This mass could easily be predicted if the drying mass constant of the material is known and used in a model equation developed with respect to basic drying principle; provided the initial mass of the material is known. In this study, the determination of dry mass constants for banana, pawpaw and Negro pepper were carried out by using these fruits freshly harvested; and cut/classified into three size ranges namely small, medium and large. Each sample was oven dried at 55^{0}C. The moisture content (MC) of each size was determined at hourly interval till constant mass of the sample was observed. `The moisture content against time of drying, drying rate against drying time and moisture content against the ratio of initial mass (M_0) to mass at any given time (M_t) were plotted for each size range of the fruit sample. The drying rate curves obtained were similar to typical drying curve; and so the data generated are assumed to be accurate. The slope of the plots of MC against M_0/M_t are the drying mass constants with value 0.3205 ± 0.1704 for Negro pepper, 0.2915 ± 0.0086 for banana while pawpaw had 0.0590 ± 0.0310.

KEYWORDS: *Moisture content, Drying mass constant, Negro pepper, banana, pawpaw*

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I. INTRODUCTION

Preservation or retardation of microbial growth in food material to discourage spoilage is essential since food is perishable commodity. Usually at a certain moisture content in a material, the microbial and enzymatic activities would be insignificant to cause food spoilage. There are several methods that could be applied on a food material to have its moisture content reduced (https://edblog.hkecity.net, 2019; Henríquez et al., 2014). One of the methods of reducing water content of a material to encourage long shelf life is drying. The drying process involves heat and mass transfer. The application of heat to remove water content of the material may be through convection, conduction and radiation. It has been observed that some food materials such as fruits may have water content up to 80% or more; and significant amount of vitamins and minerals that are useful to human. The high water content causes them to be highly susceptible to spoilage through the activities of bacteria. Therefore, the removal of water by application of heat may be carried out to preserve fruits. The drying temperature required for fruit is important because they are sensitive to heat. In drying fruit, the temperature of 55^{0}C was observed to be suitable. This is attributed to the fact that at a temperature of 60^{0}C, the chances of having most of the enzymes destroyed is high (Wilhelm et al., 2004; Lutovska et al., 2015; Idah et al., 2010).

From basic drying theory, the moisture content of a material could be expressed as:

$$\text{Moisture content (MC) wet basis (wb)} = \frac{(\text{Initial mass} - \text{Final mass})}{\text{Inital mass}} \qquad 1$$

$$\text{MC (wb)} = \frac{(M_t - M_d)}{M_t} \times 100\% \qquad 2$$

Where, M_t at time zero is denoted as M_o, and M_d is the bone dry mass (final mass/constant mass obtained)

$$\text{Also, the moisture content (MC) dry basis (db)} = \frac{(\text{Initial mass} - \text{Final mass})}{\text{Final mass}} \qquad 3$$

$$\text{MC (db)} = \frac{(M_t - M_d)}{M_d} \times 100\% \qquad 4$$

The model obtained from equation 2 could be written as (Antia et al., 2014):

$$\text{MC (wb)} = \left[1 - F\frac{[M_0]}{[M_t]}\right] \times 100\% \qquad 5$$

Where, F = drying mass constant = $\frac{M_d}{M_0}$ 6

Substitute equation 6 in equation 4 and rearrange

$$MC\ (db) = \left[\frac{1}{F\left(\frac{M_0}{M_t}\right)} - 1\right] \times 100\% \quad 7$$

In this study, the drying mass constant of some fruits are to be determined to provide a data bank for use in estimating the mass of dried material at any given moisture content of such fruit using the model equation 5 or 7; provided its initial mass is known. This is very useful especially in rural areas where sun drying is a major method of drying; as the availability of electricity is rare coupled with lack of capital, skill and technique by the small scale farmers with respect to modern drying methods. Therefore, in this regards the farmers in the rural area can discontinue drying at mass of material that would correspond to the predetermined moisture content of such material subjected to drying; so long as its initial mass has been determined. The selected fruits considered in this work are Negro pepper, banana and pawpaw. The Negro pepper (*Xylopia aethiopica*) is an angiosperm that belongs to the family Annonaceae. It has medicinal uses such as cough remedy, lactation aid, post-partum tonic, bronchitis, stomach ache and dysentery (Antia et al., 2014; Akande et al., 2014; Tairu et al., 1999). Banana (*Musa spp.*) contains vitamin A, C and B_6 that are useful to man. It has no cholesterol and is rich in fibre, contains little fat and is low in sodium. Eating banana can help to manage high blood pressure, heart disease (Omolola et al., 2015; Robinson and Sauco, 2010; Robinson, 2006). Pawpaw also known as papaya has juicy and sweet taste. It contains high amount of vitamin C, K, fibre and carotenoid (Khodabakhsh et al., 2014; Morton, 1987; Liebman, 1992).

II. MATERIALS AND METHODS

(a) Materials

The following materials were used in this study: oven, weighing balance, Negro pepper, banana and pawpaw.

(b) Sourcing of Materials

The fresh samples of the selected fruits namely: Negro pepper, banana and pawpaw were obtained from farm in Uyo, Akwa Ibom State, Nigeria.

(c) Preparation of Sample

The samples were dried in a hot air conventional oven. Prior to drying, the individual samples were cleaned, sorted and cut into three different sizes namely: large, medium, and small size samples.

(d) Determination of Moisture Content

Drying of the different samples was done in triplicate at drying air temperature of 55°C. The reduction in mass of the drying samples was monitored at an interval of 1 hour until constant mass was achieved. Digital electronic weighing balance with 0.01g precision was used for measuring the mass of the samples.

(e) Experimental Procedure

The moisture content of freshly harvested fruits samples was calculated by using equation 8 (Antia *et al.*, 2014 and Antia *et al.*, 2019) as:

$$MC\ (db) = \frac{(M_t - M_d)}{M_t} \times 100\% \quad 8$$

Where, MC (wb) is the moisture content wet basis and M_d is the bone dry mass (gram) of the samples.

During drying, the mass of the sample (M_t) at a given time t was measured. The initial mass of the freshly harvested sample (gram) at time t = 0 is denoted as M_o. Standardized values of MC and M_o/M_t were calculated for large, medium, small and bulk samples. The calculated values of the moisture content were plotted against that of M_o/M_t for each of these samples based on equation 9.

$$MC\ (wb) = \left[1 - F\frac{[M_0]}{[M_t]}\right] \times 100\% \quad 9$$

Where, F (drying mass constant) for each fruit selected was obtained as the slope of the equation 9.

This F value is the ratio of bone dry mass of the freshly harvested sample to the initial mass of the freshly harvested agricultural product sample i.e. F = $\frac{M_d}{M_0}$

III. RESULTS AND DISCUSSION

(a) Determination of Drying Mass Constant of Negro Pepper

Fig. 1 and 2 show moisture content variation with drying time for the sample sizes of Negro pepper dried at a temperature of 55°C till bone dry mass.

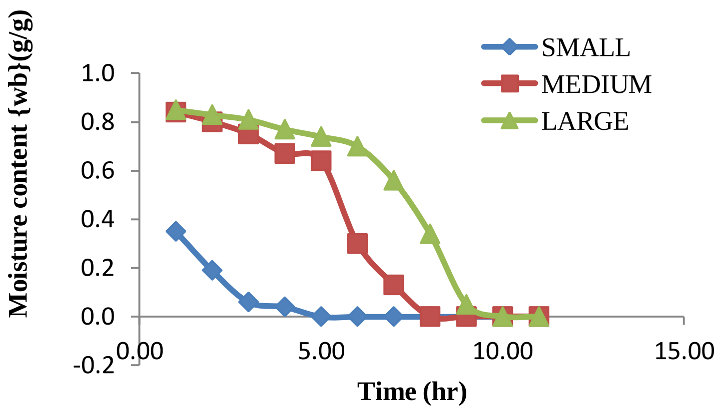

Fig. 1: Moisture content variation against drying time for the different size ranges of Negro pepper

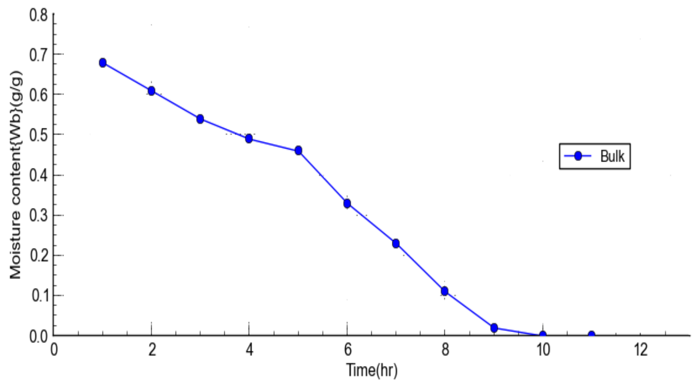

Fig. 2: Moisture content variation against drying time for the bulk Negro pepper

The moisture content for each sample size decreased with increase in time of drying. Also, the drying time increased with increase in size which points out that drying time is dependent on size of the Negro pepper sample. The drying rate (DR) against the drying time for each size of the samples is given in Fig. 3 and 4. It may be inferred that most of the surface moisture was being removed at the initial drying times; and at this period, the rate of evaporation was very high. The drying curve obtained is similar to an ideal drying curve. The drying rate for all the Negro pepper sizes decreased with increase in drying time as shown in Fig. 3 and 4. The medium size Negro pepper had the highest drying rate value at the first hour of drying. There was a short constant rate period observed at the second and third hours of drying for the large size. The same was also observed for the bulk Negro pepper at the fourth and fifth hours of drying.

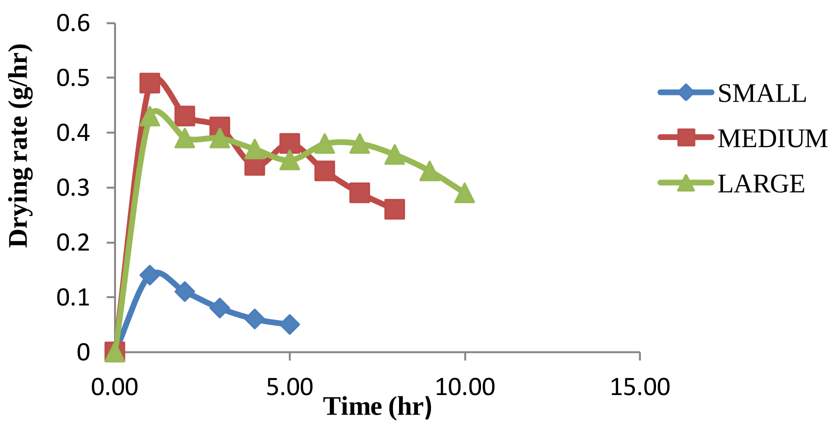

Fig. 3: Drying rate against drying time for the different size ranges of Negro pepper

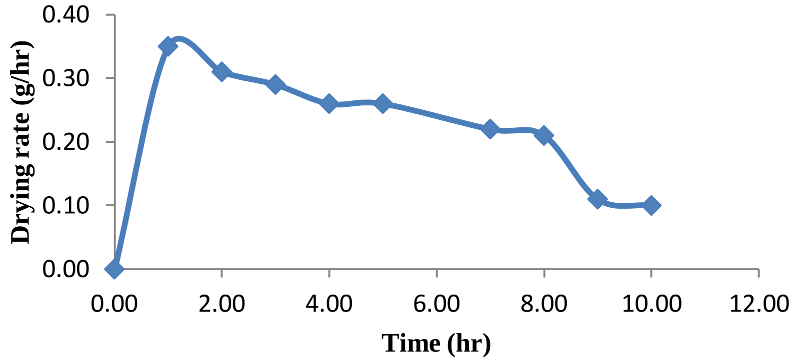

Fig. 4: Drying rate against drying time for bulk Negro pepper

Standardized values for moisture content and M_o/M_t were plotted and presented in Fig. 5 and 6.

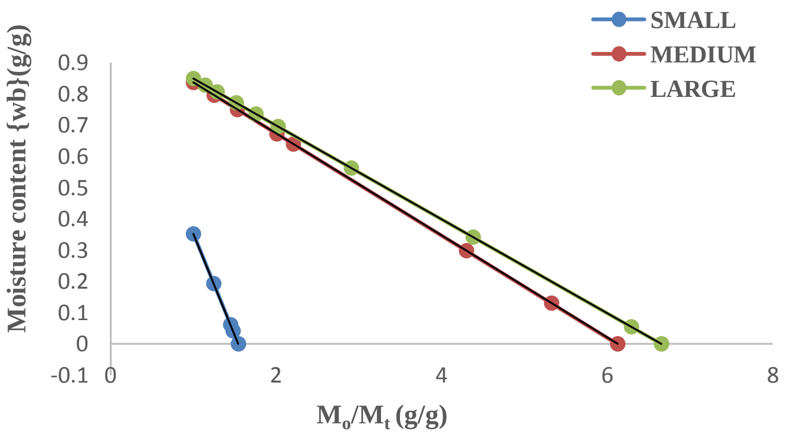

Fig. 5: Moisture content against M_o /M_t for the different size ranges of Negro pepper

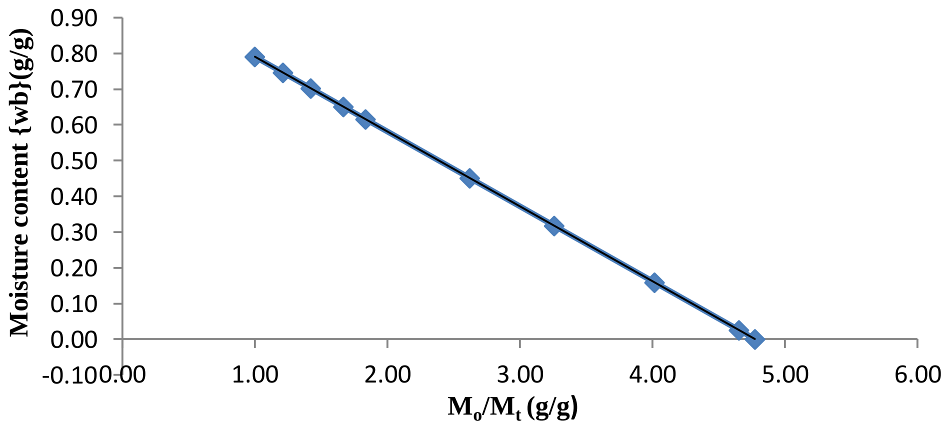

Fig. 6: Moisture content against M_o /M_t for bulk Negro pepper

From Fig. 5 and 6, the moisture content was observed to decrease with increase in M_o/M_t. The model equation has a coefficient of determination (r^2) of 1. The drying mass constants for small, medium, large size and bulk sample are 0.4879, 0.1633, 0.1503, and 0.3205 ± 0.1704 respectively.

(b) Determination of Drying Mass Constant of Banana

The moisture content variation against drying time for the various size ranges of banana dried at 55°C are given in Fig. 7 and 8.

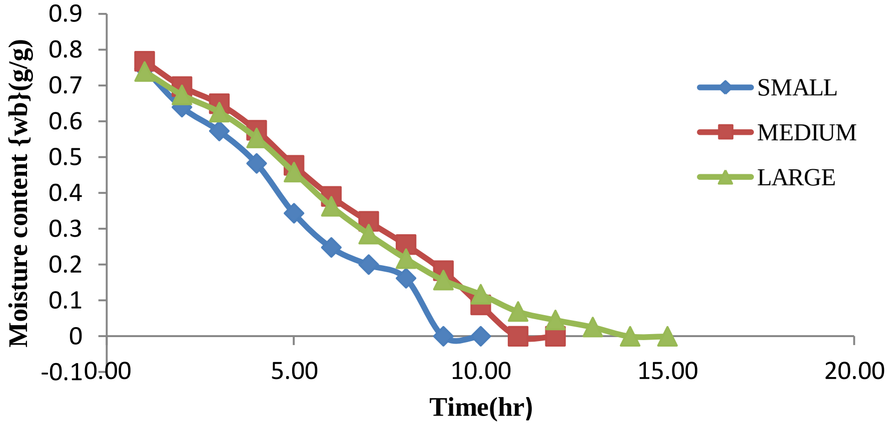

Fig. 7: Moisture content variation against drying time for the different size ranges of banana

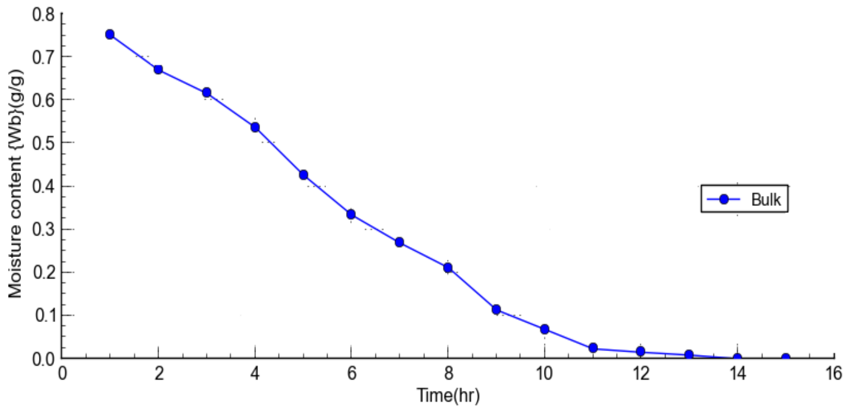

Fig. 8: Moisture content variation against drying time for the bulk banana

The moisture content of the banana samples does not depend on the sample size. This could be seen in the medium size which had the highest moisture followed by the large and lastly, the small size range. The moisture content of each sample size decreased with increase in drying time. Also, drying time increased with increase in size which implies that drying time is also dependent on size of the sample. Plots of the drying rate (DR) against drying for each size are shown in Fig. 9 and 10.

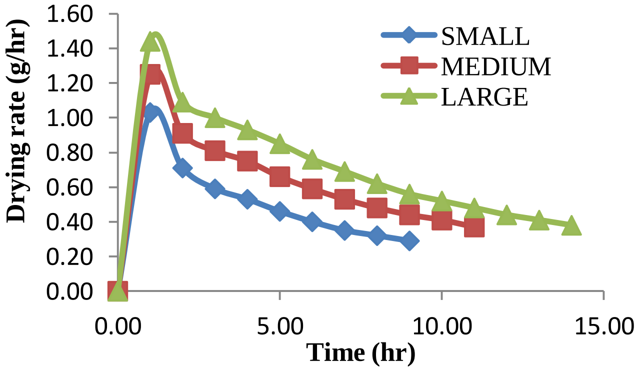

Fig. 9: Drying rate against drying time for the different size ranges of banana

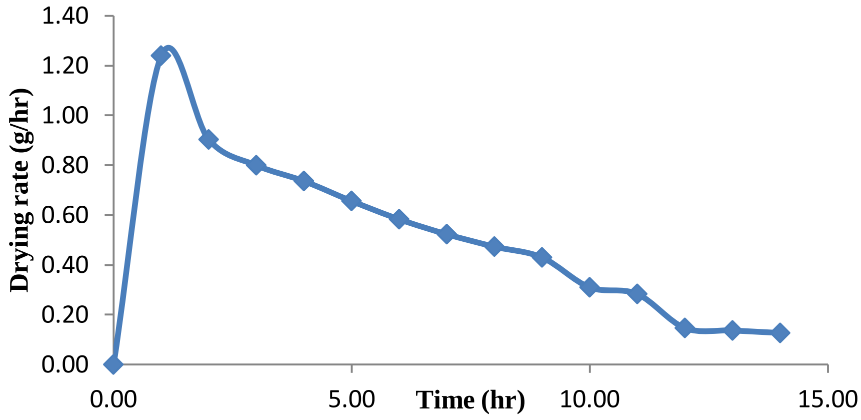

Fig. 10: Drying rate against drying time for bulk banana

The drying rate of the bulk banana obtained was found to decrease with increase in drying time as shown in Fig. 9 and 10. The large size Banana has the highest drying rate value at the second hour of drying. The curves for all the sizes had a similar pattern. M_o/M_t ratios and % MC were calculated and standardized for the different sizes of the sample. The plots of MC against M_o/M_t are shown in Fig. 11 and 12.

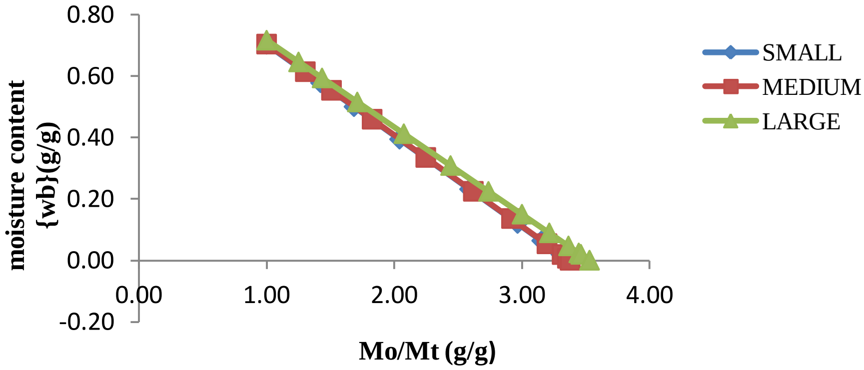

Fig. 11: Moisture content against M_o/M_t for the different size ranges of banana

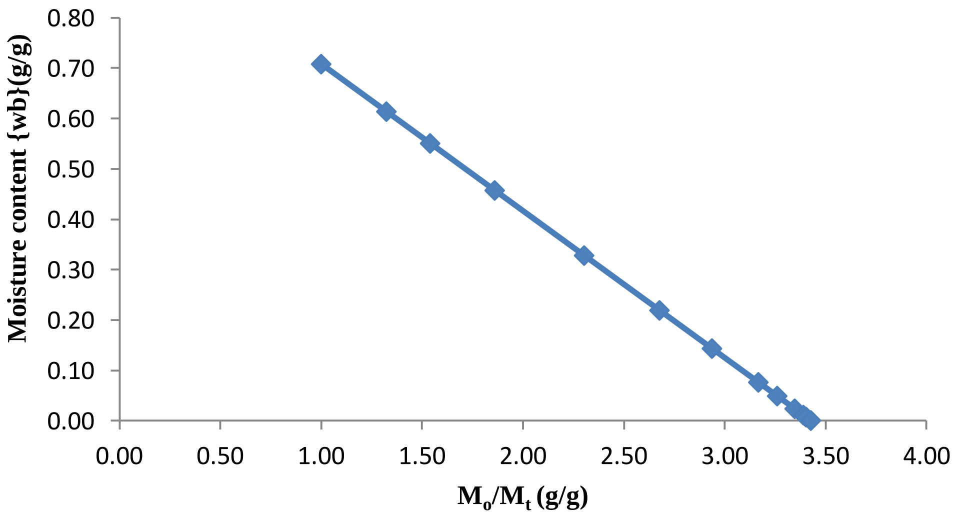

Fig. 12: Moisture content against M_o /M_t for bulk banana

It was observed that M_o/M_t values for small and medium size banana were much closed as seen in Fig. 11. The slope of the graph is the drying mass constant based on the model equation 5. The drying constant values are 0.2968, 0.2961, 0.2833, 0.2915 $\pm$ 0.0086 for the small, medium, large and bulk banana samples. R^2 was found to be equal to 1 for all the sizes.

(c) Determination of Drying Mass Constant of Pawpaw

Fig. 13 and 14 give the graph of moisture content against drying time for the various size ranges of pawpaw samples dried at 55°C.

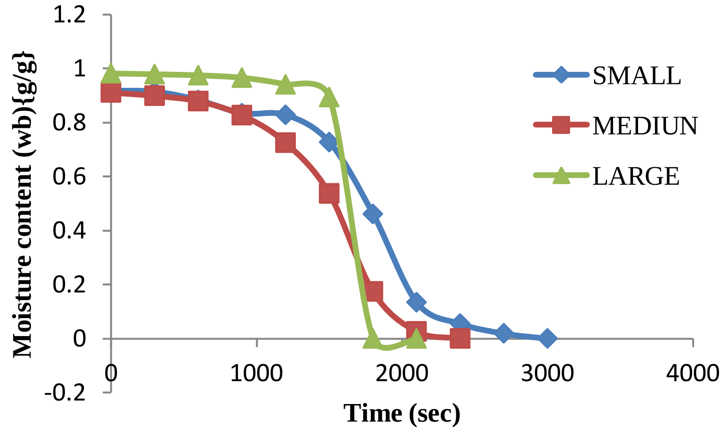

Fig. 13: Moisture content variation against drying time for the different size ranges of pawpaw

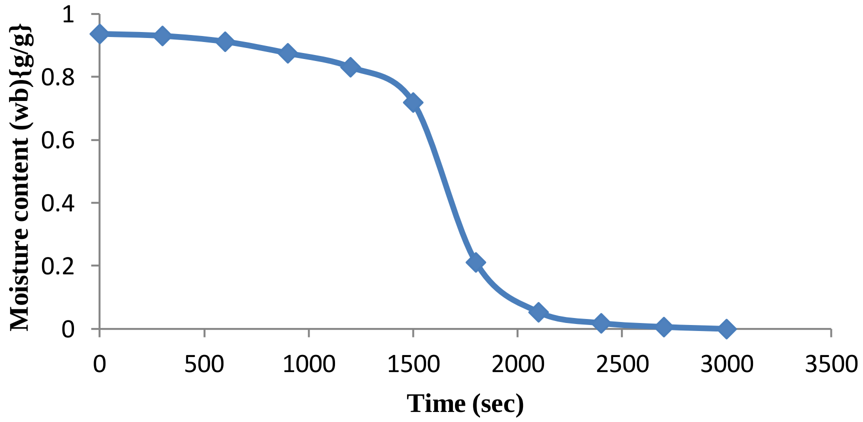

Fig. 14: Variation of moisture content against drying time for the bulk pawpaw

The plot pattern is similar to a typical drying curve. The plots of drying rate against drying time for different sizes of pawpaw coupled with bulk sample are presented in Fig. 15 and 16.

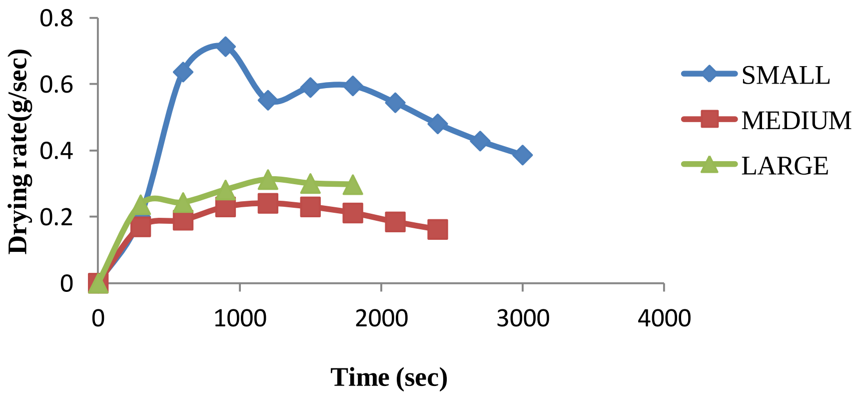

Fig. 15: Drying rate against drying time for the different sizes of pawpaw

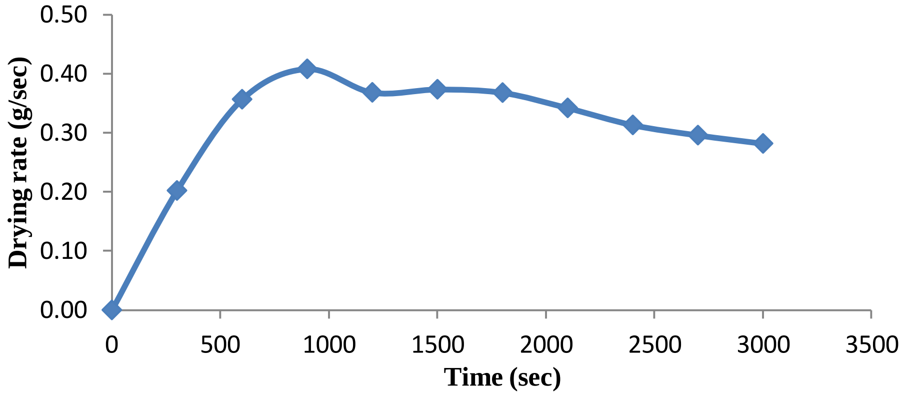

Fig. 16: Drying rate against drying time for bulk pawpaw

From Fig. 15 and 16, moisture content for each sample size decreased with increase in drying time. The drying curve obtained is similar to an ideal drying curve. The drying rate for all pawpaw sizes decreased with increase in drying time as shown in Fig. 15 and 16. Plots of MC against M_o/M_t for all sizes are presented in Fig. 17 and 18.

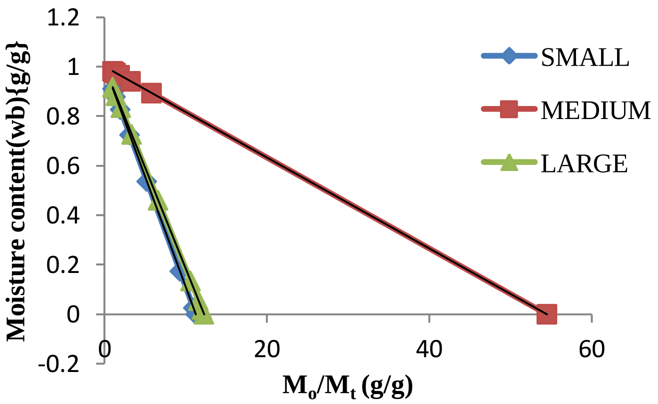

Fig. 17: Moisture content against M_o/M_t for the different size ranges of pawpaw

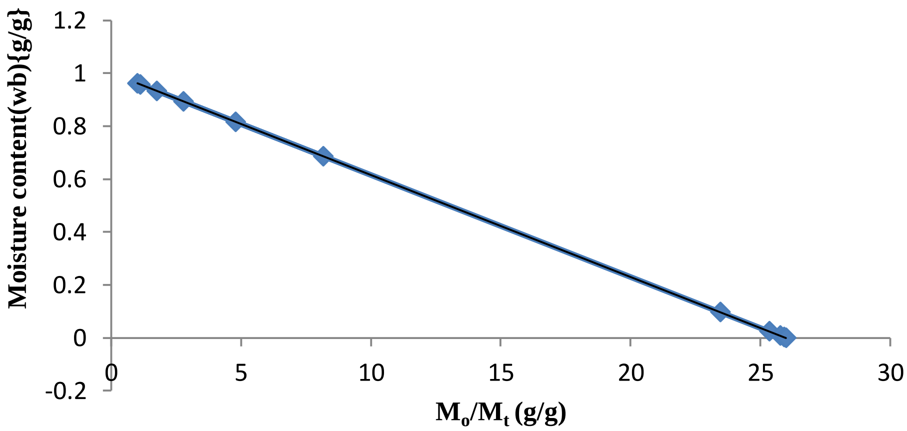

Fig. 18: Moisture content against M_o /M_t for bulk pawpaw

The drying mass constant for the small, medium, large and bulk quantities were 0.089, 0.0283, 0.0816 and 0.0590 ± 0.0310, respectively. The graphs have a coefficient of determination (R^2) of 1 for all the sizes. The plots of MC against M_o/M_t for all the sizes followed the same pattern.

IV. CONCLUSION

The drying mass constants of bulk sample for the selected fruits in this study are: 0.3205 ± 0.1704, 0.2915 ± 0.0086 and 0.0590 ± 0.0310 for Negro pepper, banana and pawpaw, respectively. These values could be used to predict their respective mass at any given moisture content during drying. Also, the increase or decrease in moisture content is not dependent on the size range of the sample.

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