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Evaluation of Drying Mass Constants for Some Selected Vegetables

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Abstract
This paper attempts to create data bank on drying mass constants of some selected vegetables. This is to facilitate the prediction of the mass of these materials with respect to any desired moisture content during drying; by applying, model equation developed based on basic drying principle. In this study, freshly harvested vegetables namely spear grass; *Gnetum africanum* and carrot were cut into three sizes: small, medium and large size. Each sample was oven dried and its mass weighed at an hourly interval until constant mass was obtained. Data were generated; and for each size range and bulk sample, graph plots of moisture content (MC) against drying time, rate of drying versus drying time were carried out coupled with plot of moisture content against the ratio of initial mass to mass at any given time (i.e., M_0/M_t) during drying. Results showed, the drying curve resembled that of an ideal drying curve; and so the generated data is reasonably valid for use in obtaining the dry mass constants. The values of drying mass constants were 0.0347 ± 0.013, 0.3098 ± 0.0138 and 0.1092 ± 0.0122, respectively for spear grass, *Gnetum africanum* and carrot.
Keywords: Drying mass constant, moisture content, spear grass, Gnetum africanum, carrot.

I. INTRODUCTION

The drying of material using sun and solar technique of drying has been in existence many centuries ago. However, it was not possible to ensure good quality of product; as it was difficult to have efficient equipment and method of determining moisture content that would prolong the shelf life of the material. Major progress has been recorded over the years in the area of developing alternative drying technologies. The drying processes include among other techniques the following: osmotic, freeze, tray, spouted bed, vacuum, microwave, ohmic and fluidized bed techniques [1]. Some basic techniques of removing water from material involve the application of heat based on conduction, convection ad radiation. In removing water from some agricultural materials such as vegetable, it is necessary to note that they contain minerals, vitamins, and digestive carbohydrates that are required for the growth and development of human. Therefore, vegetables should be dried at a temperature that would remove moisture, maintain its nutrient and increase the shelf life of the material. Drying of vegetables would also be necessary to help reducing its volume and weight, minimize cost of storage, packaging and transportation. Based on literature, the drying temperature of 55^0C – 75^0C could be acceptable for vegetables [2, 3, 4]. Studies on drying constants of some food materials have been done by different researchers using different models. Basically, moisture content could be determined as:

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

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

Where, M_d is bone dry mass, M_t is the mass of material at any time t during; and at time zero, it is denoted as M_o.

Moisture content (MC) dry basis (db) $= \frac{(\text{Initial mass} - \text{Final mass})}{\text{Final mass}}$ (3)

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

The M_d could be related to M_o as:

$$M_d = FM_o \quad (5)$$

where, F is the fraction of the initial mass obtained as bone dry mass due to removal of all evaporable water in the material. The F may therefore be termed drying mass constant.

Hence, a model equation has been developed by Antia *et al.*, [5, 6] based on equations (4) and (5) could be expressed as:

$$\text{MC (wb)} = \left\{1 - F\frac{[M_0]}{[M_t]}\right\} \times 100\% \quad (6)$$

Also, substituting equation (5) in equation (4) and rearrange, would give

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

The value of F could be obtained by carrying out drying experiment based on the model equations (6) or (7).
In food industry, vegetable is a thriving sector. The selected vegetables in this work include *Gnetum africanum*, spear grass vegetable and carrot. Gnetum is in the family *Gnetaceae* and is found in Asia, Central Africa, South America, Cameroon, Nigeria, etc. In Nigeria, *Gnetum* is called Okazi by the Igbo tribe and Afang by the Efik/Ibibio tribe. It has anti-inflammatory, antioxidant and anti-carcinogenic properties [7, 8, 9, 10, 11, 12]. The elephant grass or Napier grass known also as *Pennisetum purpureum* is in the family *Poaceae* (*Gramineae*) and can be used for livestock feed, erosion control, making fences in some Northern areas of Nigeria, preparing of special soup called 'ofe achara' by Umuahia people in Abia State of Nigeria. The aqueous extract from the leave and stem has been suggested to have some actions on tumor and can be used as diuretic, anti-diabetic, anti-gastric ulcer and anti-dysentric [13, 14, 15, 16, 17, 18]. Carrot is in the family *Apiaceae*, and is a root vegetable that has beta carotenes, vitamin A, potassium, vitamin C, vitamin B6, folic acid, thiamine, magnesium, etc [19, 4]. Generally, the drying of vegetable to achieve the desired moisture content and its corresponding mass at a given time is essential and the application of model equation (6) and (7) would be found useful, if the initial mass and drying mass constant of such vegetable are known. In this study, the drying mass constants of *Gnetum africanum*, spear grass and carrot were determined in order to provide a data bank that could be used with model equations (6) and (7) to predict easily the mass of the dried material that would correspond to the moisture content chosen, once the initial mass of the material is known.

II. MATERIALS AND METHODS

2.1 Materials
The materials that were used for this study are oven, weighing balance, *Gnetum africanum*, spear grass vegetable and carrot.
2.2 Sourcing of Materials
The fresh samples of vegetables were obtained from a farm land in Uyo, Akwa Ibom State, Nigeria.
2.3 Preparation of Sample
The individual samples obtained were cleaned, sorted and cut/grouped into three different sizes namely: large, medium, and small size samples. These samples were dried in a hot air conventional oven.
2.4 Determination of Moisture Content
The samples were classified into small, medium and large size ranges and their moisture content determined at 55°C. Each experiment was carried out in triplicate and the sample mass was measured at an hourly interval using 0.01 g precision digital weighing balance until constant mass was obtained.

2.5 Experimental Procedure
The sample moisture content was determined by employing equation (1). A graph of moisture content versus drying time was plotted using the obtained experimental data. Standardized values of MC and M_o/M_t were also calculated for each of the size range and bulk samples [5]. The values of moisture contents obtained were plotted against M_o/M_t for each of the selected vegetable samples based on equation (6). The F values were also obtained as the slope of the graph for each of the three size ranges and the bulk samples. A graph of drying rate versus drying time was plotted for all the size ranges and the bulk per sample.

III. RESULTS AND DISCUSSION

3.1 Determination of Drying Mass Constant of Spear Grass Vegetable
The moisture content variation per unit drying time for the size ranges (small, medium and large) of spear grass vegetable dried at 55°C is given in Fig. 1 and 2.

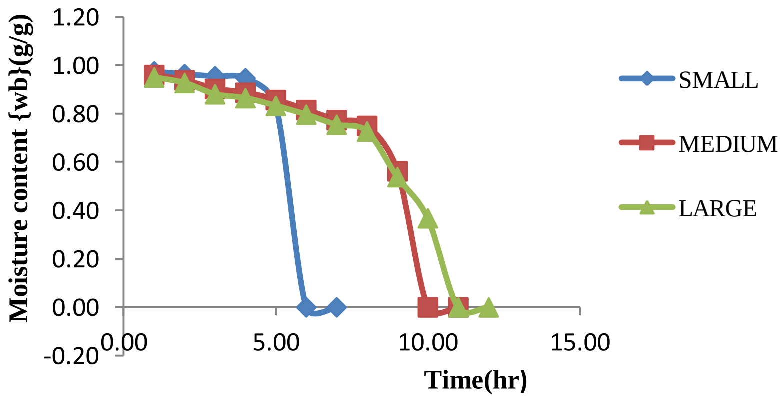

Figure 1: moisture content variation against time of drying different size ranges of spear grass vegetable

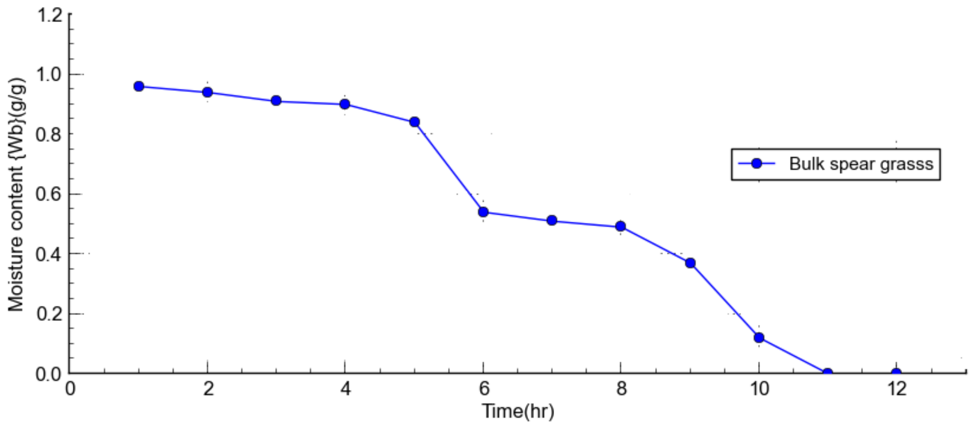

Figure 2: moisture content variation against time of drying the bulk of spear grass vegetable

It was observed that spear grass vegetable contains a lot of water in it and its moisture content increased with decrease in sample size. Also drying time increased with increase in size which implies that drying time is dependent on size of the sample. The drying rate at each drying time for each size was computed. The rate of evaporation increased dramatically at the initial drying times. During this period, most of the free moisture is being removed. The drying curve obtained is similar to an ideal drying curve. The drying rate for all the spear grass vegetable sizes decreased with increase in drying time as shown in Fig. 3 and 4

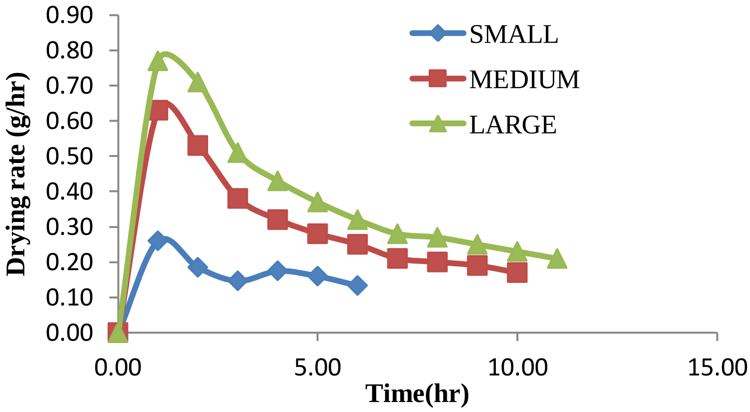

Figure 3: drying rate against drying time for the different size ranges of spear grass vegetable

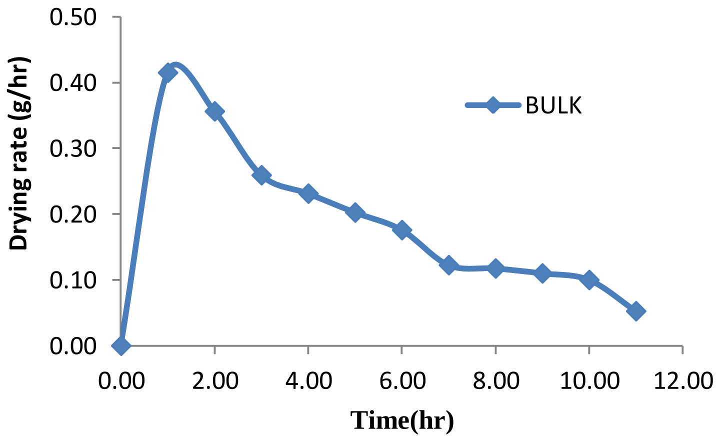

Figure 4: drying rate against drying time for bulk spear grass vegetable

The graphs of moisture content against M_o/M_t are shown in Fig. 5 and 6 based on standardized values of % MC (wb) and M_o/M_t.

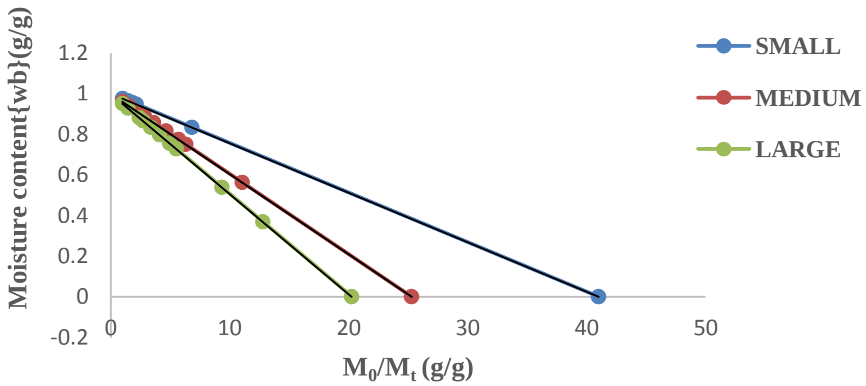

Figure 5: moisture content against M_0 /M_t for the different size ranges of spear grass vegetable

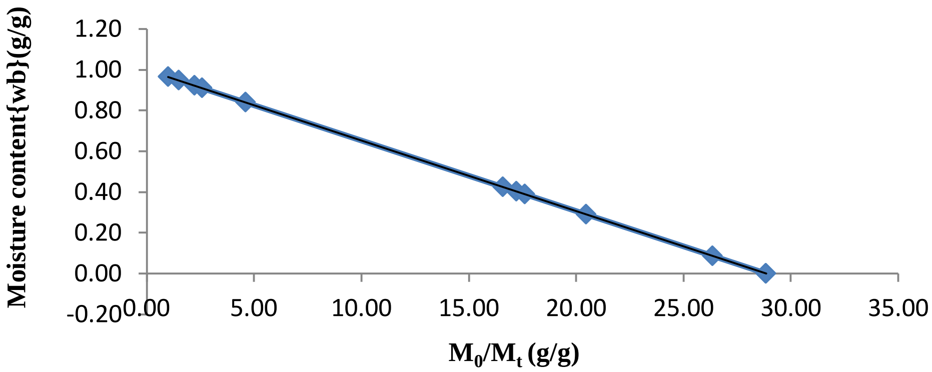

Figure 6: moisture content against M_o /M_t for bulk spear grass vegetable

A coefficient of determination (R^2) of 1 for all the sizes was obtained from the model equation. The graph of MC against M_o/M_t for all the sizes followed the same pattern. The slope of the graph gotten is equivalent to the drying mass constant F in equation (6). The drying mass constants obtained for the small, medium, large size nuts and bulk sample were 0.0244, 0.0395, 0.0494 and 0.0347 ± 0.013, respectively.

3.2 Determination of Drying Mass Constant of *Gnetum Africanum*

Fig. 7 and 8 show moisture content variation against the time of drying the three size ranges of *Gnetum africanum* dried at 55°C.

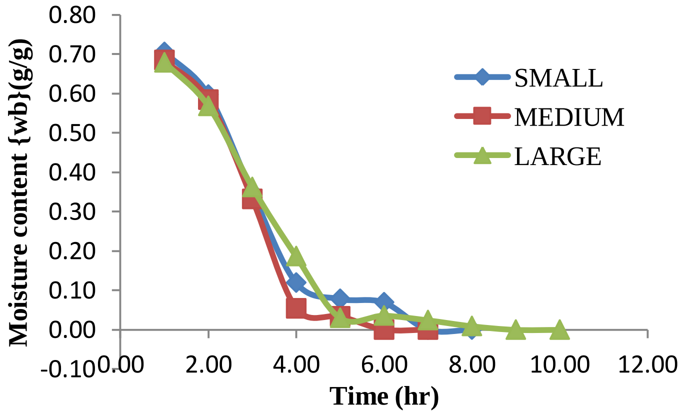

Figure 7: moisture content variation against time of drying the different size ranges of *Gnetum africanum*

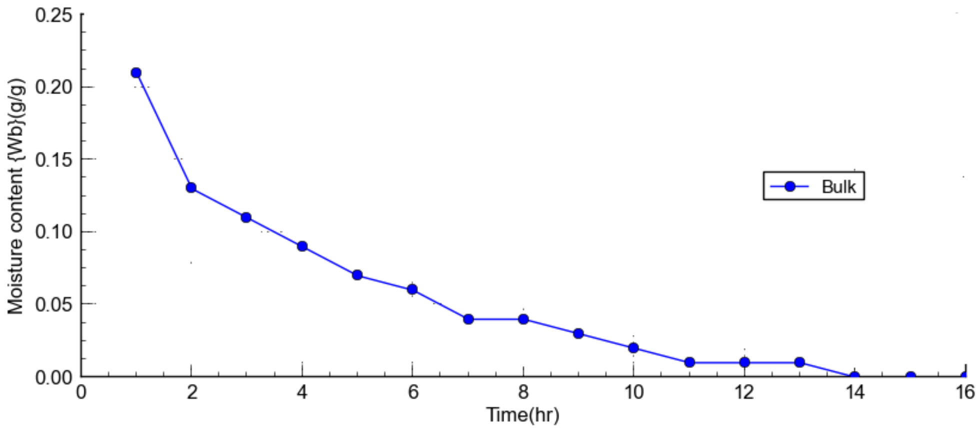

Figure 8: moisture content variation against time of drying the bulk *Gnetum africanum*

The *Gnetum africanum* samples were dried at a temperature of 55°C till dry bone mass. The moisture content of each sample size decreased with increase in drying time which gives a hint that water level in the sample reduced as the drying time increased. The drying rate (DR) gotten per unit time for each size range is given in Fig. 9 and 10.

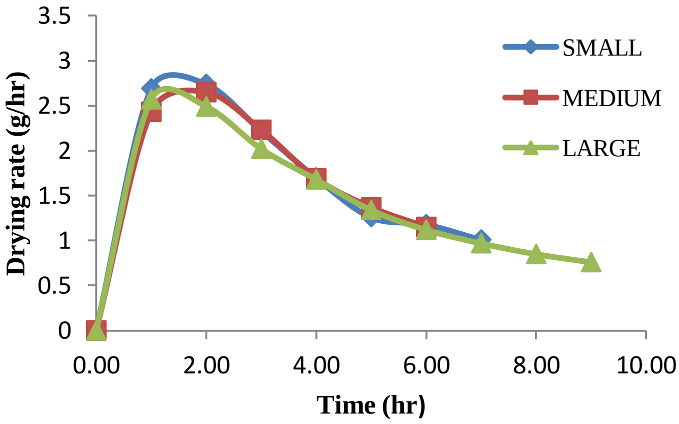

Figure 9: drying rate against drying time for the different size ranges of *Gnetum africanum*

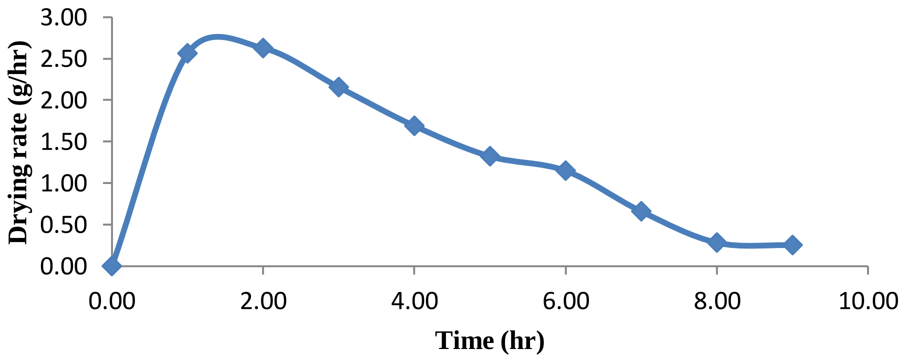

Figure 10: drying rate against drying time for bulk *Gnetum africanum*

The drying rate for all the *Gnetum africanum* sizes decreased with increase in drying time as shown in Fig. 9 and 10. The small size has the highest drying rate value at the initial hours of drying. Fig. 11 and 12 show the graph of standardized moisture content and M_o/M_t.

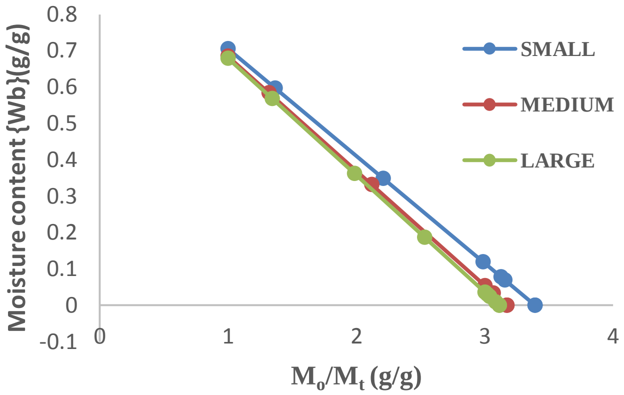

Figure 11: moisture content against M_o/M_t for the different size ranges of *Gnetum africanum*

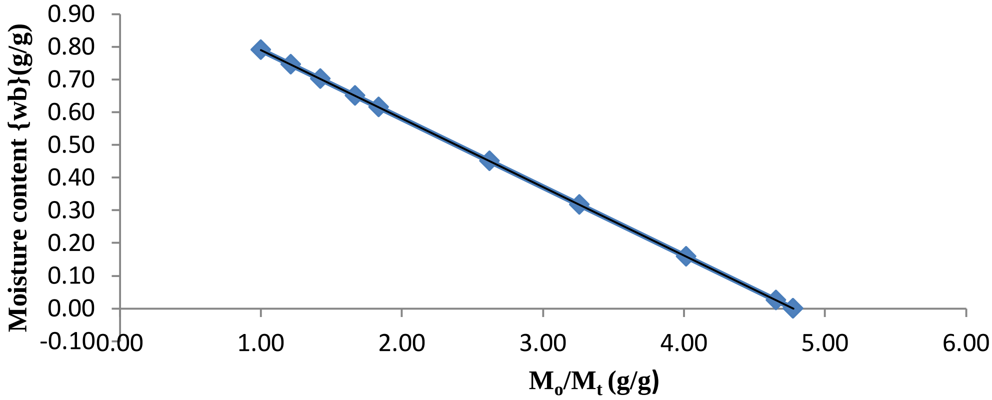

Figure 12: moisture content against M_o/M_t for bulk *Gnetum africanum*

The drying mass constants obtained were 0.2947, 0.3151, 0.321 and 0.3098 ± 0.0138 for the small, medium, large and bulk quantities, respectively. The graph has a coefficient of determination (R^2) of 1 for all the sizes.

3.3 Determination of Drying Mass Constant of Carrot

Fig. 13 and 14 show moisture content variation against drying time with respect to the various size ranges of carrot dried at 55°C till constant mass was achieved.

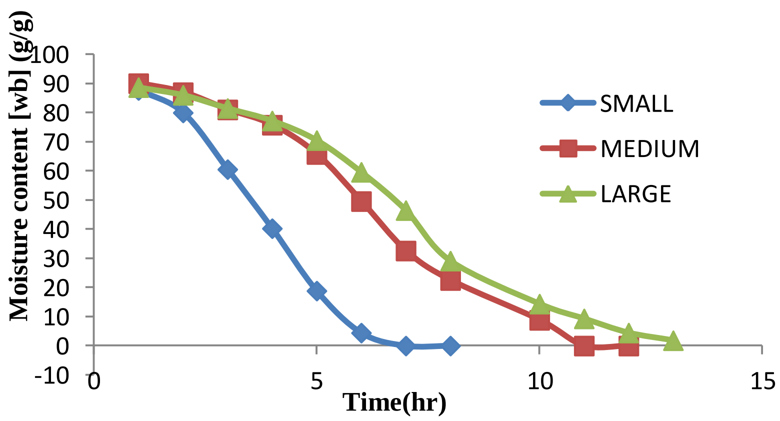

Figure 13: moisture content variation against time of drying the different size range of carrot

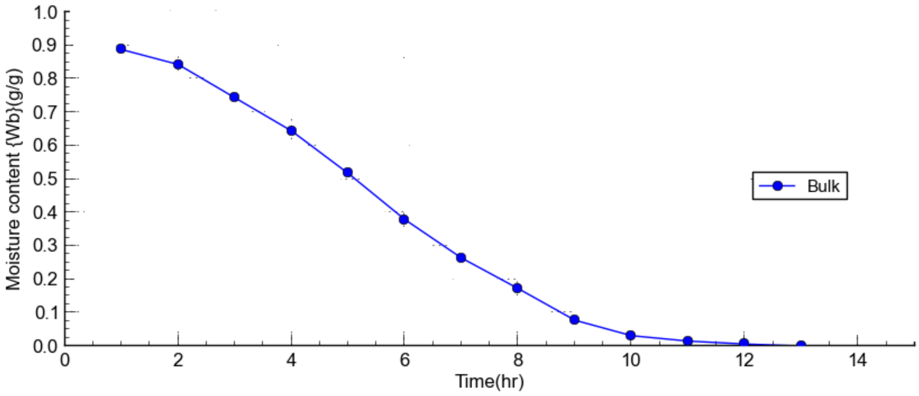

Figure 14: moisture content variation against time of drying the bulk carrot

The medium size had the highest moisture content which suggests that moisture content is not dependent on sample size. 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. The drying rate (DR) against drying time for each size and bulk sample are presented in Fig. 15 and 16.

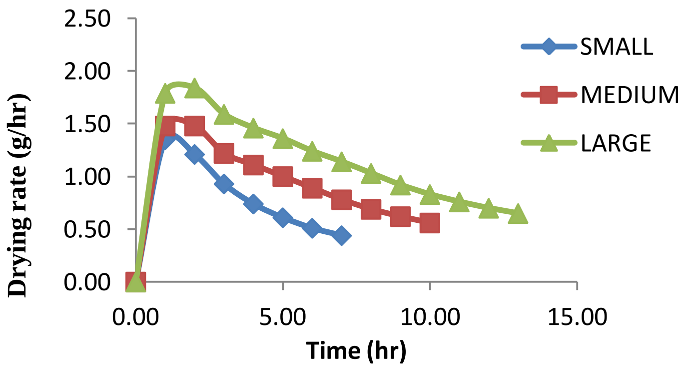

Figure 15: drying rate against drying time for the different size ranges of carrot

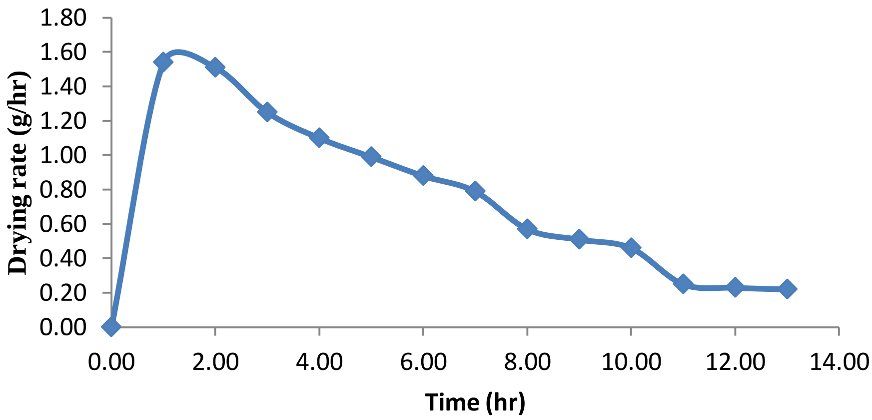

Figure 16: drying rate against drying time for bulk carrot

All the curves exhibit a falling rate period. The drying curve obtained is similar to an ideal drying curve. The drying rate for all the carrot sizes decreased with increase in drying time as shown in Fig. 15 and 16. The large size carrot had the highest drying rate at the second hour of drying. The medium shows a constant rate period at the first and second hour of drying. This further indicates that the rate of drying is not dependent on the size of the carrot. The values of standardized moisture content and M_o/M_t based on model equation (6) for the three sizes of the sample and the bulk samples are given in Fig. 17 and 18.

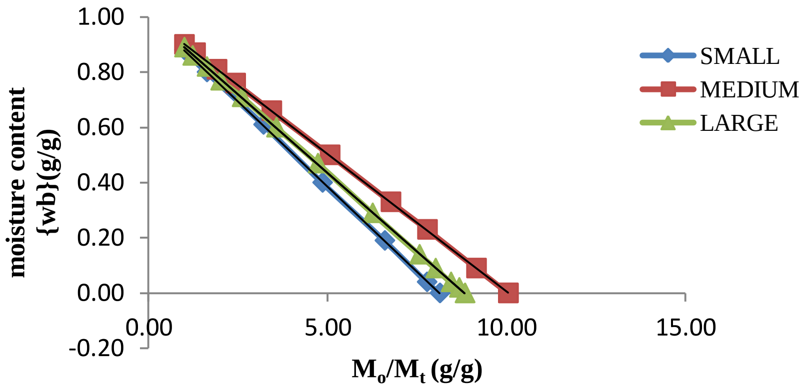

Figure 17: moisture content against M_o/M_t for the different size ranges of carrot

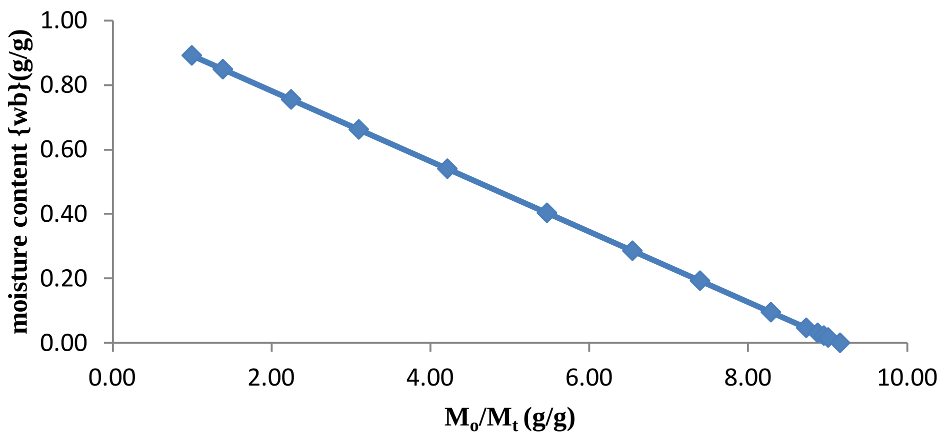

Figure 18: moisture content against M_o /M_t for bulk carrot

The drying mass constants of small, medium, large and bulk carrot are 0.1229, 0.0995, 0.1131 and 0.1092 ± 0.0122 respectively. R^2 values = 1 for all the sizes.

IV. CONCLUSION

The drying mass constants based on equation (6) are 0.0340 ± 0.0131, 0.3098 ± 0.0138 and 0.1092 ± 0.0122 for spear grass, *Gnetum africanum,* and carrot.

The drying mass constants obtained could aid in the determination of desired moisture content (MC) which corresponds to a certain mass (M_t) of the selected material if initial mass of fresh sample is known.

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