

# Determination of Drying Constants of Some Selected Roots and Tubers

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## ABSTRACT

In an attempt to easily determine the desired moisture content at any time (t), of selected freshly harvested roots and tubers (yellow cassava, carrot, cocoyam and yam) of economic importance subjected to drying under unsteady temperature conditions such as sun drying, especially in the rural areas where there is no electricity or funds availability to acquire suitable drying equipment by local farmers; the drying constants based on established model that is anchored on mass of the material at any time t was carried out. In this study, three mass classifications, namely: small, medium and large were prepared for each material and subjected to oven drying at a given temperature till bone dry mass. The experimental values obtained were computed and graphs plotted to obtain the slopes as drying constants of values 0.3114, 0.1092, 0.3736 and 0.3790 for bulk samples of yellow cassava, carrot, cocoyam and yam respectively.

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**Keywords:** Yellow cassava, Carrot, Cocoyam, Yam, Drying constants

## INTRODUCTION

Drying is a term used to describe the removal of water from material. Drying may be affected by temperature, size of material, time of exposure of material and nature of the material, etc (Antia et al., 2019). Temperature and time seems to be a major controlling factor especially when conventional dryers are employed. The major reason for drying agricultural products is to facilitate the reduction in moisture content.

This allows for safe storage over a long period of time, reduction in weight and volume hence minimize packages, transportation cost and storage (Doymaz, 2007). Various models have been proposed by researchers, in an attempt to obtain drying rate constant for use in predicting the time of drying to obtain any desired moisture content of the material (Hazarika and Datta, 2014; Uwem *et al.*, 2018 ). However, in some cases of drying, there is fluctuation in the temperature of the heat source. For example, sun drying is the major available method of drying for local farmers with no capital to purchase drying equipment or no electricity in their operational environments. Hence, the time of drying becomes inconsistent to be used for predicting or monitoring the drying time to obtain any desired moisture content of a material subjected to drying. Therefore, the mass of the material could be the only dependent variable to be used to predict when to stop drying to obtain the desired moisture content. In this circumstance, it is necessary to have a data bank of various drying constants of materials rather than their drying rate constants. These values of drying constants when employed in an established model would be used to predict mass vis-a-vis time to stop drying of such material in order to obtain the desired moisture content irrespective of the drying conditions (Antia *et al.*, 2014). It is necessary to emphasize that drying constant is not the same as drying rate constant as the latter is in terms

of time while the former is in terms of mass changes at any time (t) undergone by the material with respect to its initial mass when the material is freshly harvested.

In this study, some selected roots and tubers commonly grown in Nigeria and are of immense economic importance; hence require preservation by the local farmers who in some cases have no modern drying sources, non-availability of capital for acquiring drying equipment and no steady source of heat, etc were used. The selected roots and tubers in this research work are carrot, yam, cassava and cocoyam.

Carrot (*Daucus carota subsp. sativus*) could exist in colours such as orange, purple, red, white, black and yellow (Sifferlin and Aloyanders, 2018). It is a source of beta carotene, vitamin A, potassium and cholesterol lowering pectin, vitamin B<sub>6</sub>, vitamin C, folic acid, thiamine and magnesium. Doymaz (2004) worked on convective drying of carrot and observed that the moisture diffusivity increases with increase in temperature. Hosain *et al.* (2012) employed thin layer experiment to determine the layer drying characteristics and energy consumption of carrot slice in a microwave dryer.

Yam is in the family of *Dioscoreaceae* of the genus *Dioscorea* (Uyigue and Achadu, 2018). It is one of the primary sources

of food energy in Nigeria. Drying would ensure the reduction of moisture content of the yam and so would inhibit microorganism growth among other benefits.

Cassava (*Manihot esculenta*) is edible woody shrub with large roots. In Africa, it has increase significance because of its diverse uses, affordability, tolerance to environmental stresses and high productivity where other crops fail. There are many varieties of cassava. The ordinary varieties are generally white while yellow flesh is another variety. However, these varieties have similar characteristics. Drying provides a solution to maintain the quality of the tuber, improve the storability of the products and reduced the cyanogenic glucoside content (Westby, 2002). A study by Agiriga and Iwe (2018) on drying rate of selected varieties of shredded cassava at various times of harvest using motorized shredder recommend that a combination of parameters such as harvesting time, shred diameter, drying time (second) and temperature prevent quick spoilage and quicken drying of cassava shreds.

Cocoyam (*Colocasia esculenta*) belongs to Araceae family (Akanbi *et al.*, 2004). They are source of dietary carbohydrate. It is relatively high in protein, fat, vitamins (vitamin A and C, thiamine, calcium, niacin, iron, phosphorus and mineral (Ihekoronye and Ngoddy, 1985). Cocoyam contains digestible starch (Lewu *et al.*, 2019). Some of the products from cocoyam are cocoyam chips, flour and porridge. Cocoyam is affordable and helps in reducing the malnutrition in rural area in Nigeria. However, cocoyam has high water content and so, it is susceptible to deterioration; and therefore requires effective drying for its preservation (Afolabi *et al.*, 2014).

**THEORY**

Usually, to obtain moisture content of a material, the material bone dry mass need to be known. Thus, at bone dry mass, a certain percentage of water which is the maximum allowable evaporated water has to be given off. The moisture content obtained at this point for freshly harvested materials of mass ( $M_{sy}$ ) is the maximum percentage of moisture content of the material. The initial mass of the material ( $M_{im}$ ) immediately after harvesting is equal to  $M_{sy}$

Now, let Q be a certain fraction that represent the maximum possible evaporated water in the material; and would result in obtaining a final mass ( $M_{fm}$ ) (Antia *et al.*, 2014).

$$M_{fm} = Q M_{sy} \quad (1)$$

Based on basic drying principles, material moisture content (MC) dry basis (db) or wet basis (wb) is given as:

$$MC (wb) = \frac{[Initial\ mass - final\ mass]}{Initial\ mass} \quad (2) \quad MC (db) =$$

$$\frac{[Initial\ mass - final\ mass]}{Final\ mass} \quad (3)$$

The percentage of moisture content wet basis can be re-written as:

$$\% MC (wb) = \left( \frac{M_{im} - M_{fm}}{M_{im}} \right) \times 100 \quad (4)$$

$$\% MC (wb) = \left( \frac{M_{im} - Q M_{sy}}{M_{im}} \right) \times 100 \quad (5)$$

$$\% MC (wb) = \left( 1 - Q \left[ \frac{M_{sy}}{M_{im}} \right] \right) \times 100 \quad (6)$$

$$MC (wb) = 1 - Q \left[ \frac{M_{sy}}{M_{im}} \right] \quad (7)$$

Equation (7) is a model and Q value may be termed as drying constant. The value of Q for any material whose freshly harvested mass is known could be obtained by plotting MC (wb) against  $\left[ \frac{M_{sy}}{M_{im}} \right]$  to have Q as the slope of the graph. Thus, when the drying constants are known for materials, it is easy to predict the moisture content of such freshly harvested product once the mass of the material at any time is obtained.

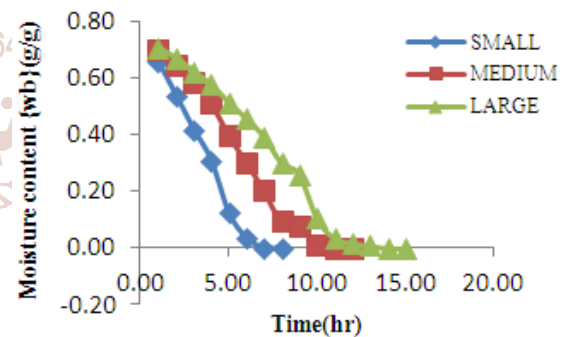
**METHOD**

Freshly harvested roots and tubers such as yellow cassava, carrot, cocoyam and yam were sourced, then cleaned, sorted and cut into three masses classified as small, medium and large ; and then weighed. These mass classifications were subjected to drying at temperature of 70 °C, except carrot at 55 °C using a convectional hot oven until bone dry mass was obtained. The experimental values obtained were then computed to obtained moisture content (weight basis) and the corresponding ratio of initial mass at time t = 0 of the freshly harvested material to the mass at any time (t) during the drying period. A plot of MC versus  $\frac{M_{sy}}{M_{im}}$  based on (7) was carried out and the slope of the graph obtained as value of Q. Thus, value of Q was now substituted into the model (7). The model was now tested for validity and thereafter employed for freshly harvested materials in order to predict moisture content of the material, once the mass at any given time (t) during drying is known.

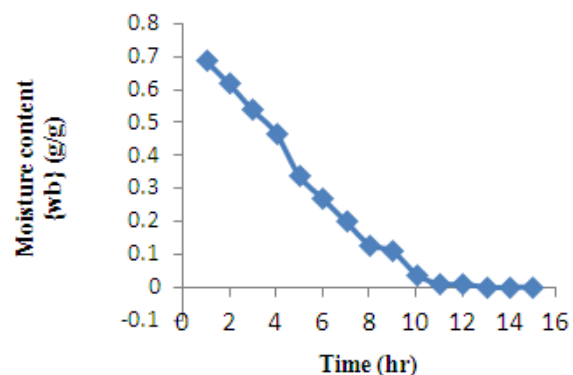
**RESULTS AND DISCUSSION**

**A. Determination of Drying Constant of Yellow Cassava**

A temperature of 70°C was used to dry yellow cassava till a constant mass was obtained. Changes in moisture content per unit time were computed and plots of moisture content per unit time are given in Fig. (1) and (2).



**Fig.1: Variation of moisture content against drying time for the different mass classifications of yellow cassava.**



**Fig. 2: Variation of moisture content against drying time for the bulk yellow cassava.**

All the curves exhibit a falling rate period. The moisture content of each sample mass classification decreased with increase in drying time. Also, drying time increased with increase in mass classifications which implies that drying time is also dependent on mass classifications of the sample. The plots of drying rate versus drying time for each mass classification and bulk sample are given in Fig. (3) and (4) respectively.

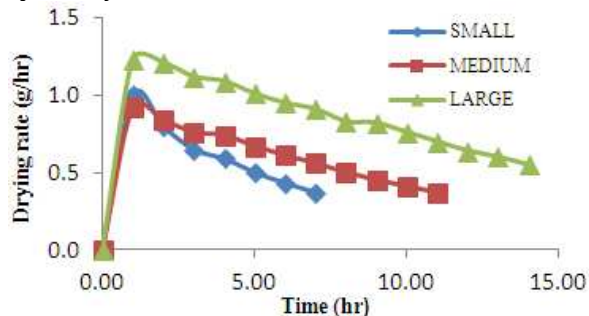


Fig. 3: Drying rate against drying time for the different mass classifications of yellow cassava.

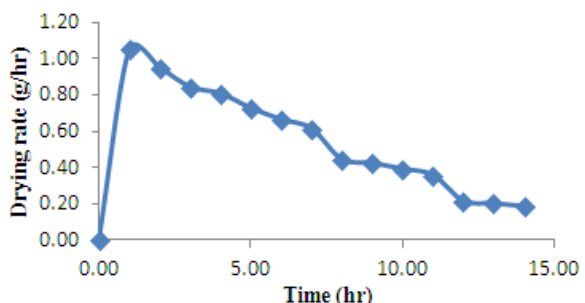


Fig. 4: Drying rate against drying time for bulk yellow cassava.

The curves exhibit typical drying curves. Based on (7),  $M_{sy}/M_{im}$  ratio was computed and standardized for the different mass classification. Plots of moisture content, wet basis (MC [wb]) are presented in Fig. (5) and (6).

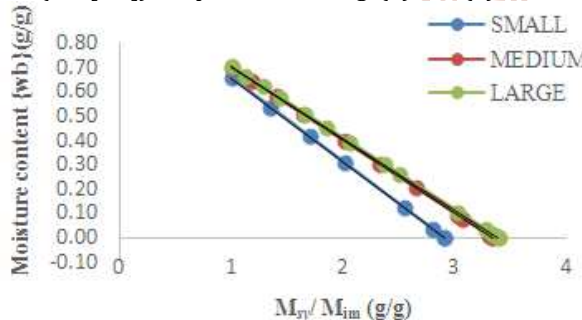


Fig. 5: Moisture content against  $M_{sy}/M_{im}$  for the different mass classifications of yellow cassava.

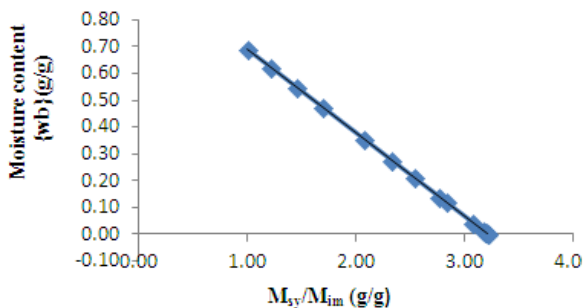


Fig. 6: Moisture content against  $M_{sy}/M_{im}$  for bulk yellow cassava.

The slopes of the graphs which are equivalent to the drying constants were  $0.3436, 0.2998, 0.2952,$  and  $0.3114 \pm 0.0268$  for small, medium, large and bulk yellow cassava respectively.

**B. Determination of Drying Constant of Carrot**

Fig. (7) and (8) show the variation of moisture content against drying time for the various mass classifications of carrot dried at 55°C till constant mass was achieved.

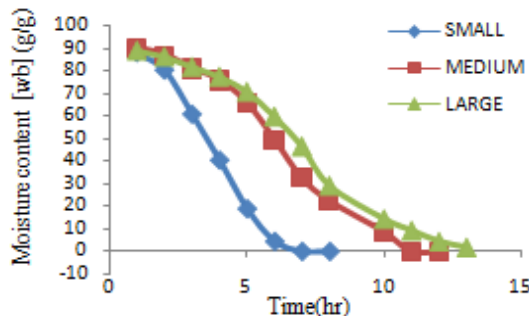


Fig. 7: Variation of moisture content against drying time for the different mass classifications of carrot.

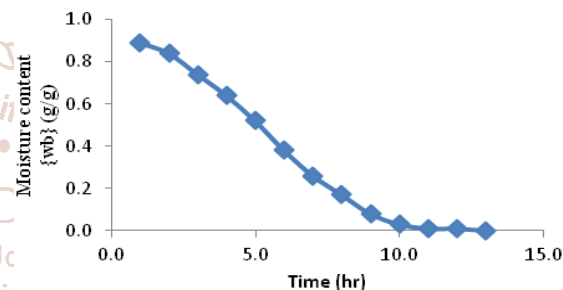


Fig. 8: Variation of moisture content against drying time for the bulk carrot.

The moisture content of each classified sample mass decreased with increase in drying time. All the curves exhibit a falling rate period. The drying rate (DR) gotten per unit time for each mass classified and bulk sample are given in Fig. (9) and (10) respectively.

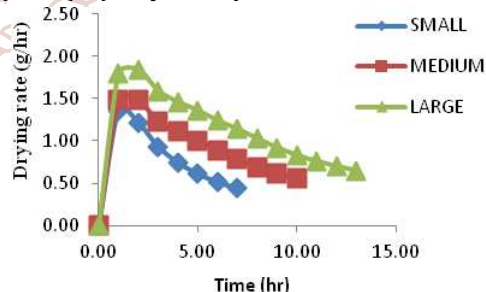


Fig. 9: Drying rate against drying time for the different mass classifications of carrot.

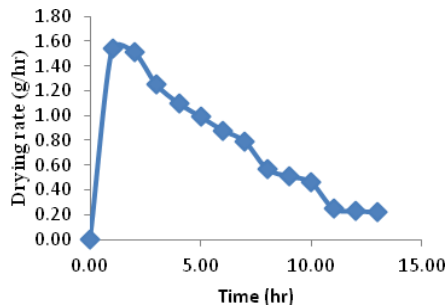


Fig. 10: Drying rate against drying time for bulk carrot.

The drying curve obtained is similar to ideal drying curve. The values of moisture content and  $M_{sy}/M_{im}$  based on model (7) for the different mass classifications of the samples are given in Fig. (11) and (12).

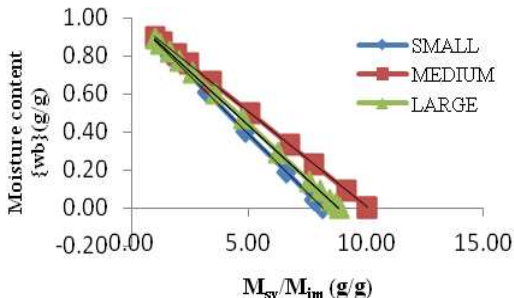


Fig. 11: Moisture content against  $M_{sy}/M_{im}$  for the different mass classifications of carrot.

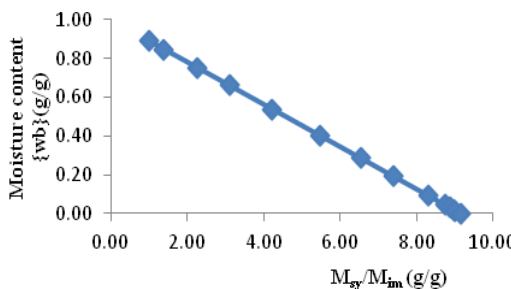


Fig. 12: Moisture content against  $M_{sy}/M_{im}$  for bulk carrot.

The drying constants of small, medium, large and bulk carrot are 0.1229, 0.0995, 0.1131 and  $0.1092 \pm 0.0122$  respectively.

**C. Determination of Drying Constant of Cocoyam**

Fig. (13) and (14) show the changes in moisture content per drying time for all the mass classifications of cocoyam dried at 70°C.

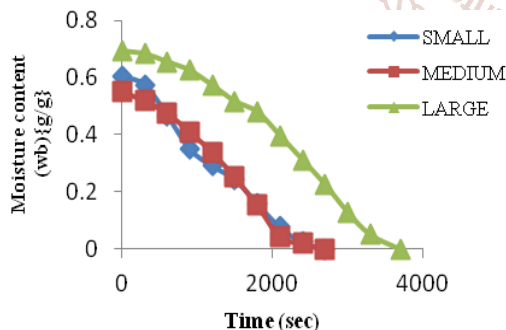


Fig. 13: Variation of moisture content against drying time for the different mass classifications of cocoyam.

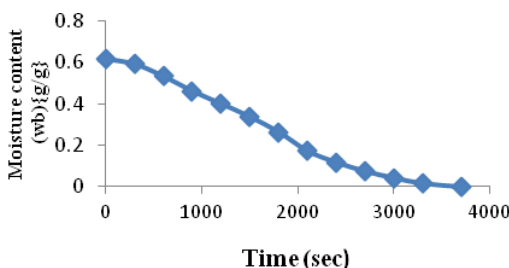


Fig. 14: Variation of moisture content against drying time for the bulk cocoyam.

The moisture content of each classified sample mass decreased per unit time. The drying curve obtained is similar to an ideal drying curve. The drying rate for all the cocoyam mass classifications decreased with increase in drying time. The drying rates (DR) gotten per unit time for each classified mass are given in Fig. (15) and (16).

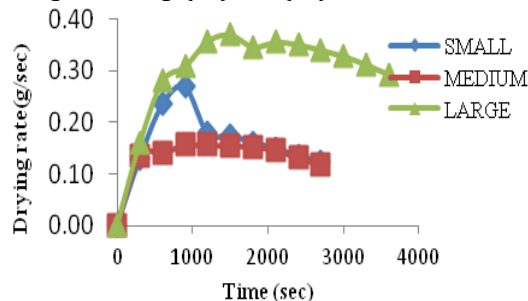


Fig.15: Drying rate against drying time for the different mass classifications of cocoyam.

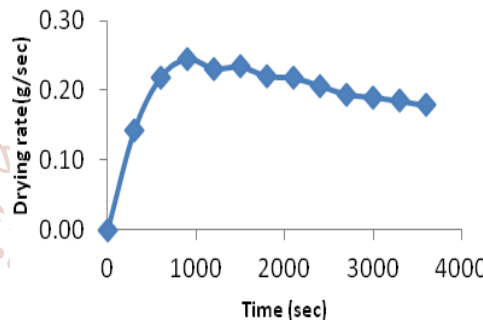


Fig.16: Drying rate against drying time for bulk cocoyam.

Moisture content and  $M_{sy}/M_{im}$  values were computed and the plots of moisture content against  $M_{sy}/M_{im}$  are shown in Fig.(17) and (18).

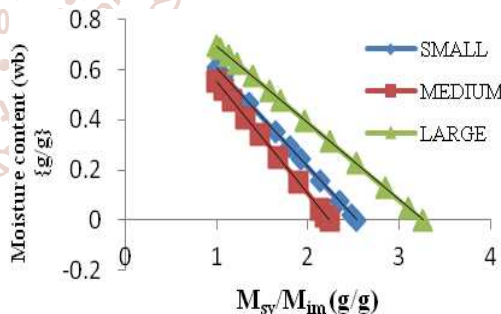


Fig.17: Moisture content against  $M_{sy}/M_{im}$  for the different mass classifications of cocoyam.

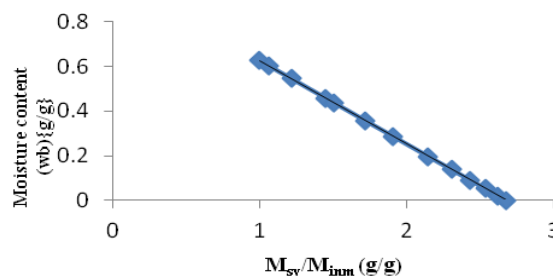
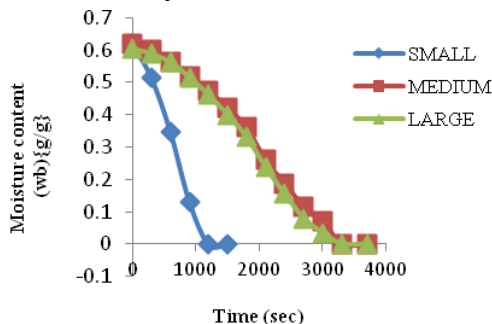


Fig.18: Moisture content against  $M_{sy}/M_{im}$  for bulk cocoyam.

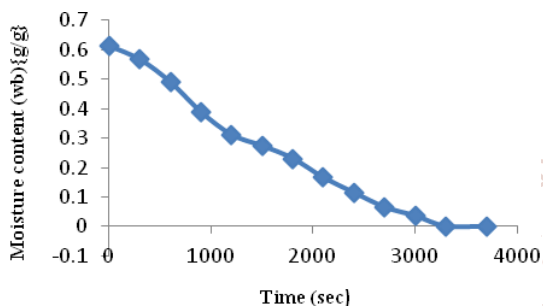
The drying constant for the small, medium, large and bulk cocoyam are 0.3945, 0.4477, 0.3066, and 0.3736 respectively.

**Determination of Drying Constant of Yam**

Fig. (19) and (20) show the variation of moisture content against drying time for the various mass classifications of yam dried till bone dry mass at 70°C.

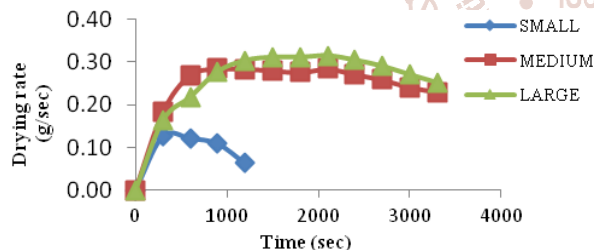


**Fig. 19: Variation of moisture content against drying time for the different mass classifications of yam.**

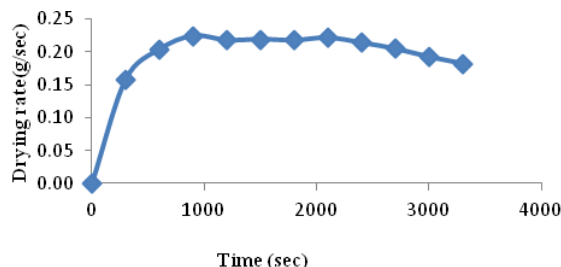


**Fig. 20: Variation of moisture content against drying time for the yam.**

The moisture content of each classified sample mass decreased with increase in drying time. The drying curve obtained is similar to an ideal drying curve. The drying rate for all the classified yam masses decreased with increase in drying time as shown in Fig. (21) and (22).

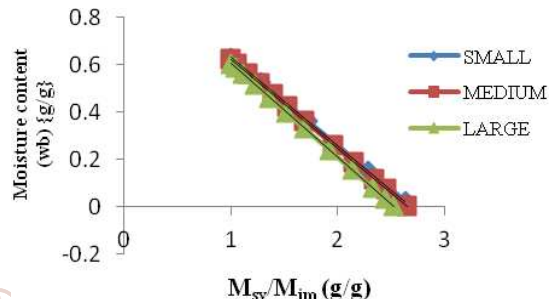


**Fig. 21: Drying rate against drying time for the different mass classifications yam.**

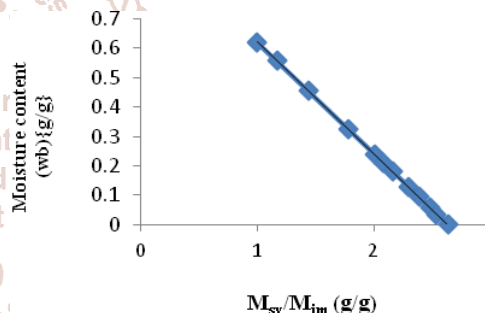


**Fig.22: Drying rate against drying time for bulk yam.**

The plots of MC against  $M_{sy}/M_{im}$  are presented in Fig. (23 and 24).



**Fig.23: Moisture content against  $M_{sy}/M_{im}$  for the different mass classifications of yam.**



**Figure 24: Moisture content against  $M_{sy}/M_{im}$  for bulk yam.**

The slope of the graph is equivalent to the drying constant of the model (7). The drying constant for the small, medium, large and bulk samples were 0.3714, 0.3780, 0.3964, and 0.379 respectively.

In summary, the drying constants for yellow cassava, carrot, cocoyam and yam are presented in Table 1.

**TABLE 1: DRYING CONSTANTS FOR DIFFERENT SAMPLE SIZE RANGES AND THEIR STANDARD DEVIATIONS.**

Sample	Sample Mass Classification	Drying Constant (f)	Mean (Bulk f)	Deviation, $d = x - \text{mean}$	Variance	Standard Deviation
Yellow cassava	Small	0.3436	0.3114	0.0322	0.0007	0.0268
	Medium	0.2998	0.3114	-0.0116		
	Large	0.2952	0.3114	-0.0162		
Carrot	Small	0.1229	0.1092	0.0137	0.0001	0.0122
	Medium	0.0995	0.1092	-0.0097		
	Large	0.1131	0.1092	0.0039		
Cocoyam	Small	0.3945	0.3736	0.0209	0.0052	0.0722
	Medium	0.4477	0.3736	0.0741		
	Large	0.3066	0.3736	-0.0670		
Yam	Small	0.3714	0.3790	-0.0076	0.0002	0.0134
	Medium	0.3780	0.3790	-0.0010		
	Large	0.3964	0.3790	0.0174		

### PRACTICAL APPLICATION

The (7) could be employed to know when to stop drying based on the mass of material predicted with respect to any desired moisture content during drying; once the initial mass of freshly harvested material is known.

### CONCLUSION

The model (7) is useful in predicting moisture content of material at any time (t) during drying. The yellow cassava, carrot, cocoyam and yam have values of their drying constant as presented in Table 1.

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