Sorption Characteristics of Cocoyam (*Colocasia Esculenta*) at Different Temperatures

Canadian Journal of Agriculture and Crops
Vol. 4, No. 2, 200-207, 2019
e-ISSN: 2518-6655

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ABSTRACT

The exploitation of cocoyam (*Colocasia esculenta*) for food is limited to direct consumption of primary products which often result in huge post-harvest losses. This study reports the development and storage of flour from cocoyam with the intent of establishing suitable storage conditions for its storage. Fresh cocoyam corms obtained from the Federal University of Technology (FUTA) Research Farm, were peeled, washed, sliced, oven-dried and then milled into the powder. Insights into the is essential to maintain Good keeping quality of food materials is a function of the relationship between their air relative humidity (expressed as water activity (aw)) and equilibrium moisture content. The gravimetric method was used to determine the adsorption isotherms of cocoyam flour. In the range of temperature (20 - 40 °C) and a_w (0.10 - 0.80) typical of the tropical environment, different concentrations of concentrated acid (H_2SO_4) solutions were used to vary the condition of the research area. The experimental data were compared with six widely recommended models for food sorption isotherms (GAB, BET, Oswin, modified Oswin, Hasley & Smith). The plot of moisture sorption isotherms also resulted in a sigmoidal shape which is influenced by temperature variation. Generally, the Modified Oswin model was found most suitable to describe the sorption isotherm of cocoyam flour.

Keywords: *Sorption, Cocoayam, Water activity, Gravimetric method.*

DOI: 10.20448/803.4.2.200.207
Citation | Olumurewa J. A. V.; Olabinjo O.O.; Olaide, F. (2019). Sorption Characteristics of Cocoyam (*Colocasia Esculenta*) at Different Temperatures. Canadian Journal of Agriculture and Crops, 4(2): 200-207.

Funding: This study received no specific financial support.
Competing Interests: The authors declare that they have no competing interests.
History: Received: 15 August 2019/ Revised: 19 September 2019/ Accepted: 25 October 2019/ Published: 2 December 2019
Publisher: Online Science Publishing

Highlights of this paper

- This study reports the development and storage of flour from cocoyam with the intent of establishing suitable storage conditions for its storage.
- The Modified Oswin model was found most suitable to describe the sorption isotherm of cocoyam flour.

1. INTRODUCTION

In many developing countries of the world, roots and tubers such as cassava (*Manihot esculenta*), sweet potato (*Ipomoea batatas*), yam (*Dioscorea sp*), and cocoyams (*Colocasia esculenta and Xanthosoma sagittifolium*) are important household food security and income crops. Very good sources of starch and they satiate consumers. Predominantly, they are cultivated in West Africa and are important food crops for more than 400 million people worldwide [1, 2].

According to Enwere [3] corms and cormels can be eating cooked or pounded with cassava or yam to make *fufu* to be eaten with stew, also they are used as a thickener in soup preparation. The flours if precooked find good uses in pie filing, the binder in sausage and as emulsifiers in food stems [4]. Cocoyam is processed into chips for continuous food supply during the hunger periods. It was reported that the nutritional and chemical composition of cocoyam if duly utilized, would alleviate the problem of food insecurity in the tropics [5].

Some species of cocoyam contain high content of calcium oxalate crystals (780 mg per 100 g) and this has been responsible for the acridity or irritation caused by cocoyam. Oxalates tend to precipitate calcium and make it unavailable for use by the body. But this can be reduced by peeling, grating, soaking and fermentation processes [6]. Added to the problem of oxalate is that they are very susceptible to physical damage during harvesting which leads to high post-harvest losses.

According to Onyeike, et al. [7] corms and cormels will store well by processing them into flour, and according to Kwarteng and Towler [8] its flours can store much longer than the tubers of cocoyam. The knowledge of physical and other engineering characteristics of cocoyam will enhance its application in other food systems and improve its marketing potential. Cocoyam flour is good for making biscuits or as composites in bread production [9-11]. Apart from the consumption of various cocoyam foods, rural households also vend them as a way of coping with food insecurity. Advances in cocoyam processing and marketing could enable poor households in Nigeria to strengthen their food availability, storability, access and utilization [12].

Food sorption isotherm is the thermodynamic relationship between water activity (a_w) and the equilibrium moisture content (EMC) of food product at constant temperature and pressure. According to Famurewa and Oladejo [13] this knowledge is highly important to Food Processing Engineers to design and optimize drying equipment and for quality, stability and shelf-life predictions. This study aims at studying how cocoyam can be made into flour to increase its utilization by predicting the suitable model for storage of cocoyam flour.

2. MATERIALS AND METHODS

In this study, the cocoyam cultivar was obtained from the University Research Farm. The chemical (concentrated H_2SO_4) was sourced from the Food Science and Technology Laboratory of the Federal University of Technology, Akure and was of analytical grade.

2.1. Sample preparation

Cocoyam tubers were washed with clean water, peeled with a clean stainless knife, and cut into slices using FUTA Slicing Machine. The sliced cocoyam was then oven-dried at a temperature of 60 ^oC until a constant weight was achieved. The dried cocoyam tubers were then milled with FUTA Plate Mill.

2.1.1. Humidity Control

The static gravimetric procedure as described by Oyelade, et al. [14] was employed in this study. At 20, 30 & 40 °C, varying measures of H_2SO_4 were mixed with deionized water to make up a 250 ml of desiccant to give water activities (a_w) of 0.1, 0.20, 0.40, 0.60, 0.65, & 0.80, respectively. 20 grams of each of the cocoyam samples were put in a petri dish and the petri dish inside desiccators. The desiccators were placed in Genlab Incubator Model M75CPD (Genlab Ltd., Cheshire, England). to maintain the required temperature. Samples were being monitored in the incubator by weighing daily until constant weights were achieved. The equilibrium moisture contents of the equilibrated samples were determined on a dry basis [14]. The goodness of fit of the models was evaluated using three indicators namely: lowest of residual sum of squares (RSS) and standard error of estimate (SEE) and highest of the coefficient of determination (R^2).

3. RESULTS AND DISCUSSION

Table 1 shows the values of equilibrium moisture contents at different water activities. The higher the water activities, the higher the equilibrium moisture contents and vice versa. Table 2 presents the model constant values for sorption isotherm of cocoyam flour at 20, 30 and 40 °C respectively. The goodness of fit of the models was evaluated using R^2, RSS and SEE, and their values are as shown in Table 3. The indicators are determined as defined in Equation 1, Equation 2 and Equation 3.

$$RSS = \sum(Mcal - Mpred) \quad (1)$$

$$\text{SEE} = \sqrt{\sum(Mcal - Mpred)^2/\text{df}} \quad (2)$$

$$R^2 = 1\text{- RES/TES} \quad (3)$$

Where:

M_{cal} = Calculated Equilibrium Moisture Content.

M_{pred}= Predicted Equilibrium Moisture Content.

df = Degree of Freedom.

RES = Regression Error Sum of Squares.

TES = Total Error Sum of Squares.

Table-1. Equilibrium moisture contents obtained at different water activities.

Aw	EMC(20 °C)	EMC(30 °C)	EMC(40 °C)
0.1	0.027	0.024	0.02
0.2	0.047	0.044	0.037
0.4	0.07	0.063	0.059
0.6	0.095	0.078	0.076
0.8	0.12	0.098	0.093

Table-2. Model constant values for sorption isotherm of cocoyam flour at 20, 30 and 40 °c.

Temp	Gab	Bet	Oswin	M.Oswin	Hasley	Smith
20 °C	C= 30.042 Mo=0.0329 K= 0.8035	C= 40.581 Mo=0.0329	C=0.0736 n= 0.3566	a= 0.00198 b= 0.0035 C= 0.3566	C=0.00240 n = 0.0639	C= 0.0314 n= -0.056
30 °C	C= 21.046 K= 0.7190 Mo=0.0401	C= 28.046 Mo=0.037	C= 0.0655 n= 0.3163	a= 0.0015 b= 0.002 c= 0.3163	c=0.019 n= 0.0713	c=0.00310 n= -0.045
40 °C	C= 10.662 K= 0.612 Mo=0.04072	C= 12.908 Mo= 0.039	C= 0.0608 n= 0.3417	a= 0.0013 b= 0.0015 C = 0.341	C= 0.0017 n=0.00692	C=0.0262 n= -0.0457

Table-3. Coefficient of determination (R^2), Standard error of estimate (SEE) and residual sum of square (RSS) of the sorption isotherm models of cocoyam flour.

Temp		Gab	Bet	Oswin	M.Oswin	Hasley	Smith
20 °C	R^2	0.927	0.9493	0.9898	0.9898	0.8492	0.9761
	RSS	0.017	0.00102	9.27E-05	9.27E-05	0.003099	0.00216
	SEE	-0.01139	-0.008	7.37E-03	0.00022	-0.014	1.64E-09
30 °C	R^2	0.8854	0.9317	0.9792	0.9797	0.7755	0.9554
	RSS	0.0017	0.0012	0.00013	0.00013	0.00317	0.0029
	SEE	-0.1149	0.00114	0.00032	0.00032	-0.0147	1.31E-09
40 °C	R^2	0.9076	0.9626	0.9723	0.9723	0.7834	0.9479
	RSS	0.0012	0.0012	0.00032	0.000173	0.00263	0.000319
	SEE	-0.0948	0.00389	0.00044	0.00044	-0.01276	2.3E-05.

Figure 1 represents the sorption isotherm graph for cocoyam flour at 20, 30 and 40 °C. The moisture sorption isotherms have sigmoid shape profiles for all of the three temperatures.

The equilibrium moisture content (EMC) was observed to be increasing with an increase in water activity (a_w). This finding agrees with the generally observed trend that the higher the value of a_w the more the quantity of adsorbed moisture. This corroborates the observation that at higher a_w, more water is available for binding at the active site of the solid. Many researchers have reported isotherms which followed this principle in the literature [15-22].

To validate the suitable model, the calculated EMC at different a_w determined were used against the predicted at the same a_w to plot the adsorption isotherms shown in Figures 2 to 19. The isotherms followed the characteristic type II (sigmoid shape) classification of Brunamer reported by Oyelade [18]. This is typical of isotherms of products high in starch content as observed by Onayemi and Oluwamukomi [23] and Kumar, et al. [24].

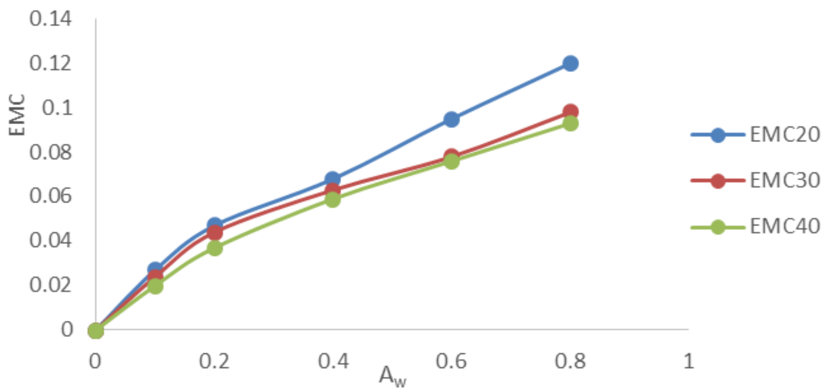

Figure-1. Sorption isotherm graph for cocoyam flour at 20, 30 and 40 °C.

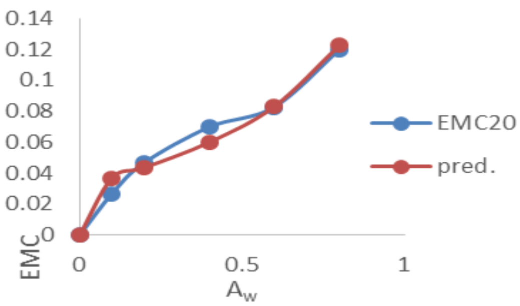

Figure-2. Oswin model validation at 20oC.

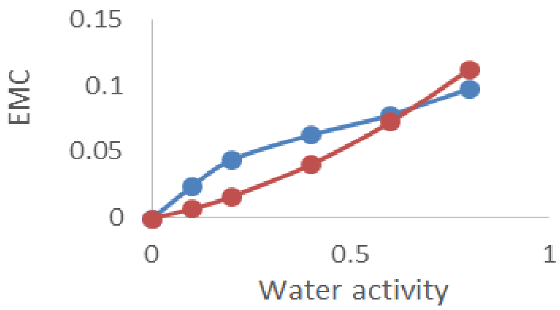

Figure-3. Gab model validation at 20 oC.

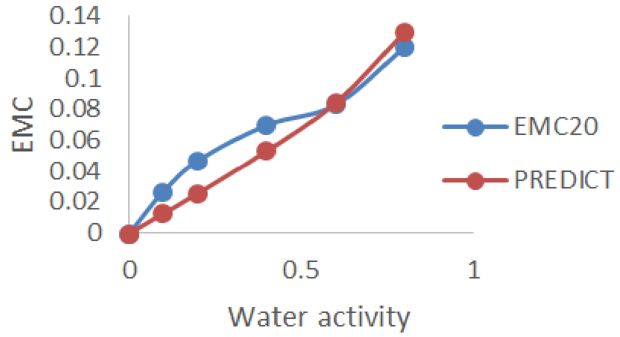

Figure-4. Bet model validation at 20 °C.

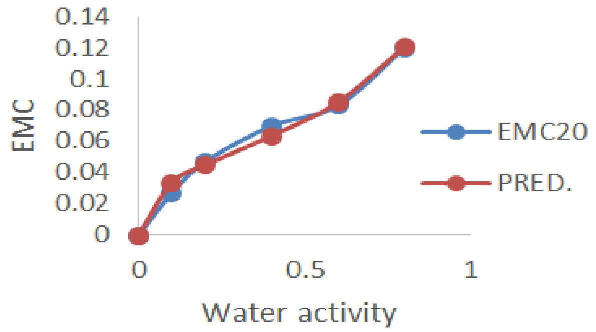

Figure-5. M.Oswin model validation at 20 °C.

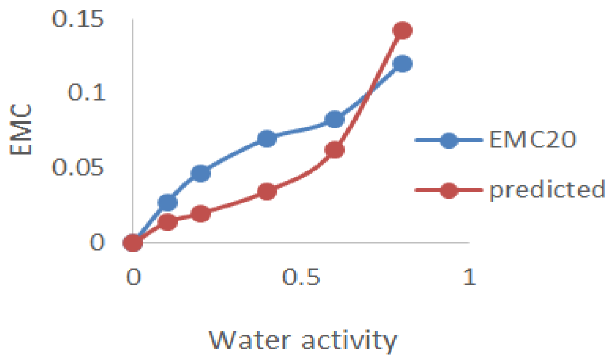

Figure-6. Hasley model validation at 20 °C.

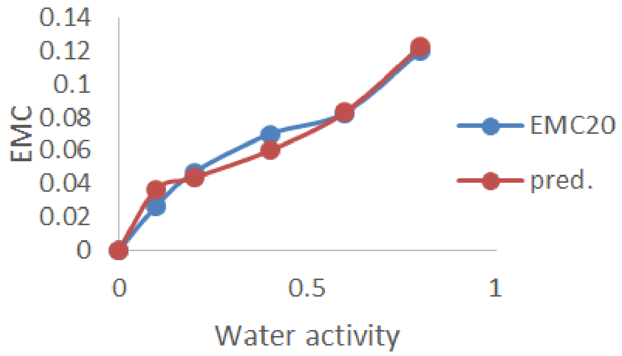

Figure-7. Smith model validation at 20 °C.

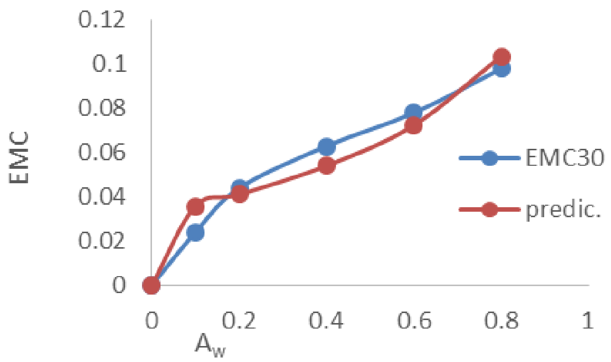

Figure-8. Oswin model validation at 30 °C.

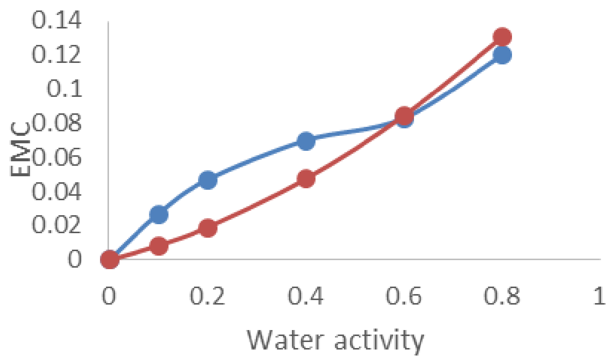

Figure-9. Gab model validation at 30 °C.

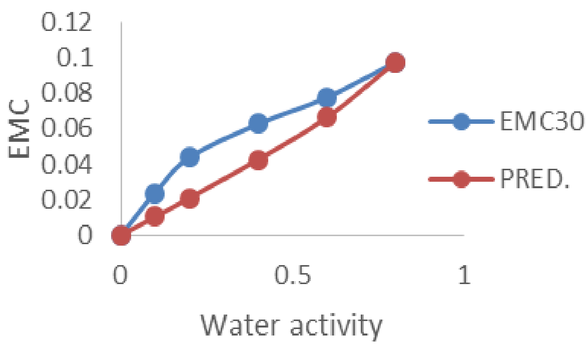

Figure-10. Bet model validation at 30 °C.

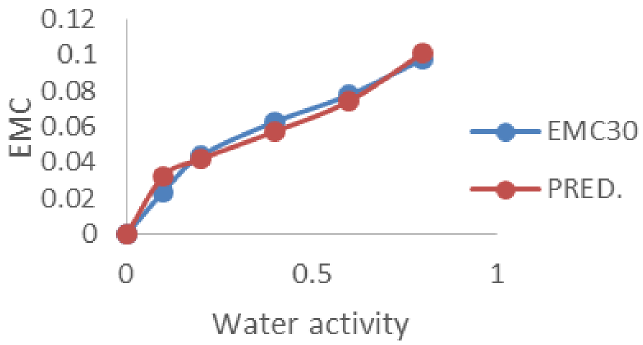

Figure-11. M.Oswin model validation at 30 °C.

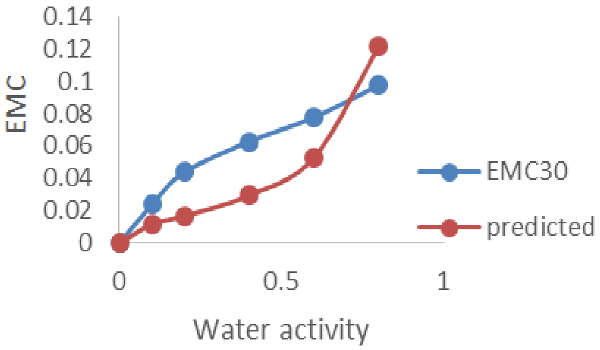

Figure-12. Hasley model validation at 30 °C.

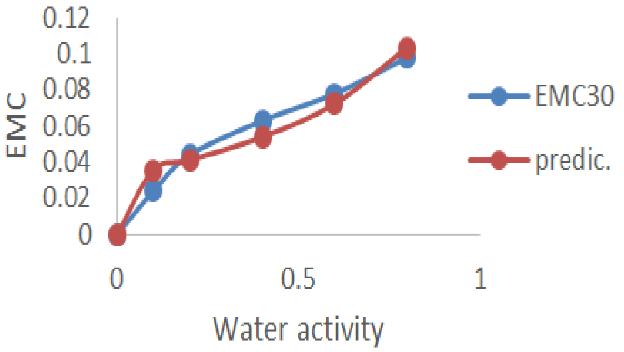

Figure-13. Smith model validation at 30 °C.

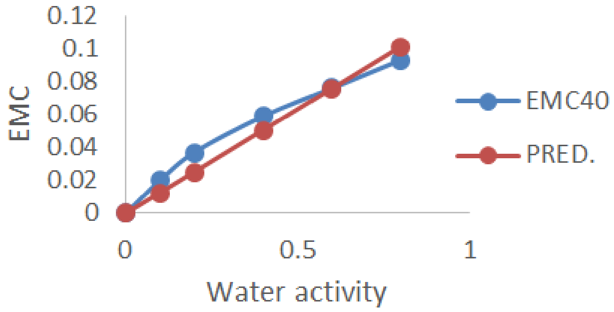

Figure-14. Oswin model validation at 40.

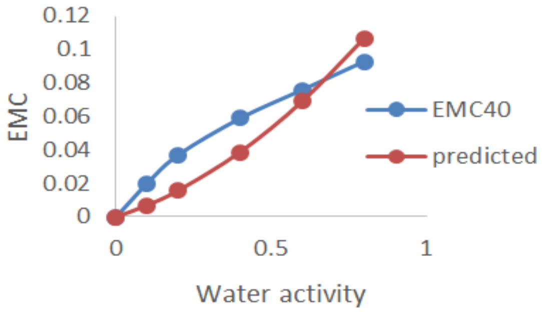

Figure-15. Gab model validation at 40 °C.

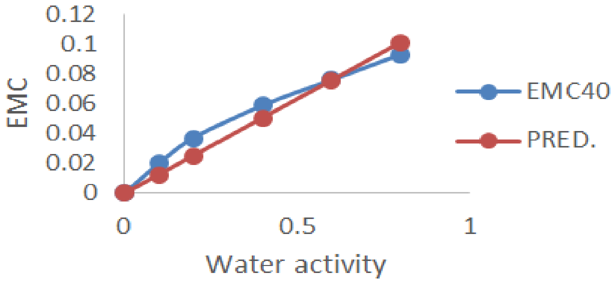

Figure-16. Bet model validation at 40.

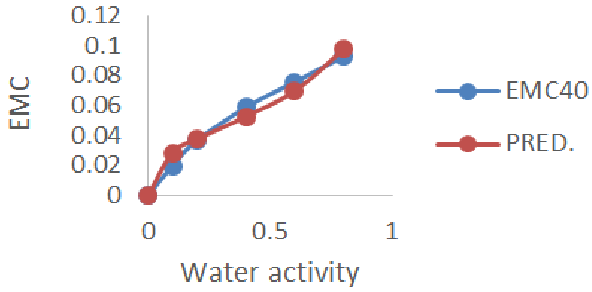

Figure-17. M.Oswin model validation at 40 °C.

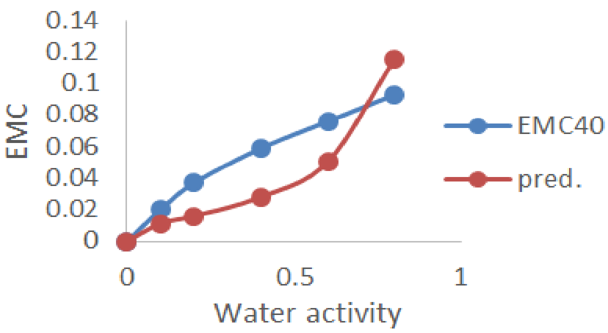

Figure-18. Hasley model validation at 40 °C.

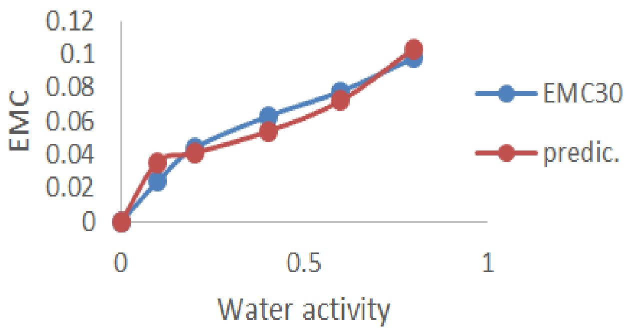

Figure-19. Smith model validation at 40 °C.

4. CONCLUSION

The investigation of sorption isotherm of cocoyam flour unveiled sigmoid shape type II which is typical for most foods [18, 23, 25]. The equilibrium moisture contents for cocoyam flours decreased with an increase in temperature [18] and at low water small amount of water was absorbed into the active site but at high water activity, much more water was absorbed leading to a rapid increase in equilibrium moisture content. Comparing the experimental data at 20, 30 and 40 °C showed that the Modified Oswin model gave the best model for the cocoyam flour and the increasing temperature in the adsorption isotherm showed a decreasing in moisture content at a given water activity.

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