Storage Stability Study of Tacca Starch at different Temperatures

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Abstract
The knowledge of water sorption Isotherm gives information about water activity of foods. This study therefore was to determine the best model for tacca starch at three different temperatures (20, 30 and 40 °C) and the best temperature at which tacca starch can be kept. Three temperatures were used for this study to determine the best region to store tacca starch either at temperate or tropics areas. Adsorption characteristics of tacca starch were determined at 20, 30 and 40 °C temperature using the static gravimetric procedure. Samples were equilibrated in desiccators containing tetraoxosulphate (VI) solution of known water activity (0.1-0.8). The appropriate constants in the sorption equation were determined by excel slover at temperature. The data obtained were fitted to seven moisture sorption models, GAB, Oswin, modified Oswin, BET, Hasley, Smith and Henderson models. The coefficients of determination varied from 0.7654 - 0.9999.Both GAB and Oswin models gave the most suitable models for describing the sorption data among the temperatures studied. A comparison of the EMC curves showed that at temperature 40 °C the tacca starch had lower equilibrium moisture contents and GAB model was found suitable for predicting tacca starch, hence tacca starch is favorable for storage in the tropical regions.

Keywords: Tacca starch, sorption, model and storage stablity

1. INTRODUCTION

Starch is the second most abundant biomass material in nature. It is found in plant leaves, stems, roots, bulbs, nuts, stalks, crop seeds, and staple crops such as rice, corn, wheat, cassava, tacca and potato. It has found wide use in the food, textiles, cosmetics, plastics, adhesives, paper, and pharmaceutical industries. In the food industry, starch has a wide range of applications ranging from being a thickener, gelling agent, to being a stabilizer for making snacks, meat products, fruit juices (Manek, *et al*., 2005).

The diverse industrial usage of starch is premised on its availability at low cost, high caloric value, inherent excellent physicochemical properties and the ease of its modification to other derivatives. The industrial utilization of starch is determined by starch morphology and its physicochemical characteristics which are typical of its biological origin (Gebre-Mariam and PC Schmidt, 2006**)**. In 2000, the world starch market was estimated to be 48.5 million tons, including native and modified starches.The value of the output is worth €15 billion per year (Le Corre, *et al*., 2010). It is a renewable and almost unlimited resource material. About 54% of the starches produced globally are utilized for food applications with 46% for non-food applications. The weak associative forces stabilizing *tacca* starch granules could be explored for its potential use as a disintegrant in the pharmaceutical sector (Maneka *et al.,* 2005).

The physicochemical and functional properties of *tacca* starch reveals that it can be compared favourably with corn and cassava starches thereby freeing cassava tubers to produce staple foods that will alleviate hunger in many African countries especially in Nigeria and tubers like *Tacca*, can be maximally utilized for the industrial starch production. The production techniques for cassava and *tacca* starches are comparable and very simple with low production costs. *Tacca* has lower fat and fibre contents compared to the other materials. The protein content is far lower than that of corn and comparable with that of potato and tapioca. On a dry basis, the starch contents of corn and wheat are higher than *tacca*, whereas that of potato and tapioca are lower. The physicochemical properties of *tacca* starch showed potential usefulness of the starch in aqueous and hydrophobic food and drug systems (Ukpabi *et al.,* 2009).

The quality of most foods preserved depends to a great extent upon their, chemical, microbiological and physical stability. This stability is mainly a consequence of the relationship between the equilibrium moisture content (EMC) of the food material and its correspondence water activity (a_w), at a given temperature. These water sorption isotherms are unique for individual food materials and can be used directly to solve food processing design problems, predict energy requirement and to determine proper storage conditions.

Water Sorption Isotherm equations can be used to predict water sorption properties of foods. There are many empirical and semi-empirical equations describing the sorption characteristics of foods. Sorption Isotherm precise shape is influenced by physical structure, chemical composition and extent of water binding within the food (Oyelade, 2008). The intent of this study therefore was to determine the storage stability of *tacca* starch flower as to be able to predict its storage life.

2.0 MATERIALS AND METHODS

2.1 Materials

The *tacca* tubers were obtained from along hill 2, OAU, Ile-Ife, Osun State Nigeria, Olokemeji road, Eruwa, Oyo State Nigeria. The packaging materials (low density polyethylene, high density polyethylene and plastic)were gotten from a local market in Akure, Ondo State Nigeria. The dessicators, digital weighing balance (AND EK-410i, A&D CO., LTD, JAPAN), Hot-air Oven and Incubator(Model IR701SG, Lec Refrigerator Plc, Britian) were gotten from Food processing laboratory, Food Science and Technology Department, Federal University of Technology Akure, Ondo State. Analytical grade of concentrated sulphric acid was gotten from PASCAL Limited, sodium metabisulphite solution.

2.2 Methods

2.2.1 Preparation of *tacca* starch

The tacca starch was prepared according to Ukpabi, *et al.*(2009), fresh roots of *Tacca in volucrata* were peeled and washed thoroughly with water to remove dirt. The washed tubers were soaked in sodium metabisulphite solution (2 L 1% w/v) at room temperature (27 °C) overnight. Thereafter, the tubers were removed and wet milled into slurry using a crusher. The paste was dispersed in a large volume of 1% sodium metabisulphite solution and filtered through muslin cloth. The suspension was centrifuged at 3500 rpm for 10 mins to facilitate removal of dirts. The supernatant was carefully decanted and the mucilage scraped off. The process was repeated three times with the mucilage on the starch scraped continuously until a pure starch was obtained. The resulting starch was dried in the sun and further dried at 60 °C in a hot air oven, pulverized, weighed and stored in sample bottles for analyses. The starch obtained was a brilliant white, crystalline, non- hygroscopic powder.

2.2.2 Storage stability studies of *tacca* starch.

The tacca starch were packed in Plastics, Low density polyethylene (LDP) and High density polyethylene (HDP) and stored in an incubator at temperatures 20, 30 and 40 °C . Samples from different packaging materials were evaluated for moisture content.

2.3 Humidity control

The static gravimetric methodas described by Oyelade, (2008) was used to bring about the required equilibration with concentrated sulphuric acid (H_2SO_4) to create storage atmosphere.Various quantities of H_2SO_4 used to make up a 250 ml of desiccant with deionised water was prepared at 20, 30 and 40 °C to obtain water activities (a_w) of 0.1, 0.20, 0.40, 0.60 and 0.80 respectively.

2.4 Determination of equilibrium moisture content

The equilibrium moisture contents of the samples were determined by static gravimetric method according to the method described by Oyelade (2008). The *tacca* starch samples were dehydrated in hot air oven to bone dry from which 20 g was weighed into different packaging materials and placed in the desiccators. Concentrated sulphuric acid was used to make up a 250 ml desiccant with distilled water which was dispensed into the desiccators with their corresponding water activity. The desiccators were maintained at water activity (a_w) values of 0.1, 0.2, 0.4, 0.6 and 0.8 respectively and kept at three different temperatures (20, 30 and 40 °C). Each sample was being weighed at intervals using a digital weighing balance until constant weight was obtained in three consecutive readings, then the samples were being assumed to be at equilibrium. The bone dry mass was determined by the oven-drying method for 8 h at 105 °C (AOAC, 2005) and equilibrium moisture contents were calculated.

2.5 Determination of Sorption Isotherm

The equilibrium moisture contents were calculated from which the moisture was plotted against water activity.

2.6 Sorption Equation

The experimental data were compared with seven widely recommended models in the literature for food adsorption isotherms which include GAB, Oswin, Modified Oswin, BET,Hasley, Smith and Henderson models. These models were chosen because of their suitability for high carbohydrate foods, simplicity and ease of evaluation (Ajisegiri *et al*., 2007). The quality offitness of the models was evaluated by calculating coefficient of determination (R^2) (Famurewa *et al.,* 2012)

3.0 RESULTS AND DISCUSSION

The equilibrium moisture content at each a_w was used in plotting the adsorption isotherm of this variety of tacca starch flour at different temperatures as shown in Figure 1. The equilibrium moisture content at each a_w represents the mean of two determinations. The sorption isotherms have a sigmoid shape. This follows the classification of Brunauer *et al,*.(1938), reported by Oyelade, (2008), Famurewa *et al.*(2012) and Igbabul *et al.*(2013) for foods high in carbohydrate type II sorption isotherm curve indicating the efficacy of Raoult's law, capillary effects and surface water interaction.

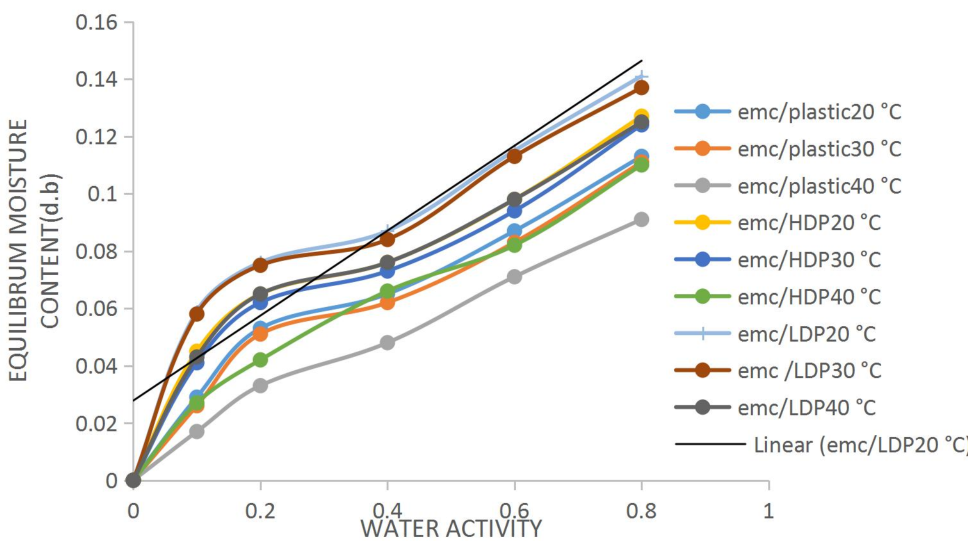

Figure 1. The graph showing the storage behavior of *tacca* starch at 20, 30 and 40 °C

3.1 Effect of Temperature on Tacca Starch

Figure 1 showed the moisture sorption isotherms of *tacca* starch with different packaging materials obtained at 20, 30 and 40 °C illustrates the moisture behavior, similar to the remaining temperatures. The moisture content decreased with increase in temperature which agreed with the results of Samapundo *et al.* (2007); Oyelade, (2008) and Famurewa *et al.* (2012). The equilibrium moisture content at each water activity represents the mean value of three replications. The equilibrium moisture content increased as water activity increased at any particular temperature and decreased as temperature increased at constant water activity (Paulo *et al.,* 2010). This indicates that *tacca* starch, at different temperatures becomes less hygroscopic as temperature increases. This also corroborate with Bajpai *et al.* (2011) for saga starch at different temperatures. From Figure 1, it was observed that moisture content was lower at 40 °C and this showed that *tacca* starch can be best stored in the tropics.

3.2 Best Models for Tacca Starch.

The models fitted for *tacca* starch flour at different temperatures are given inTables 1, 2 and 3. In fitting the curves;based on the closeness of R^2 to unity, the least values of RSS and SEE or closer to zero, the models were evaluated in terms of reliability of fit (Chowdhury *et al.*, 2005, Aviara *et al.*, 2006). The models fitted for *tacca* starch using different packaging materials at 20, 30 and 40 °C,the values of the parameters for the models which include co-efficient of fit (R^2), residual sum of square (RSS), standard error of estimate (SEE) showed that Gab model can best be used to describe the storage stability of *tacca* starch. Igbabul *et al.,*2013 stated that the GAB model fits best in various foods of plant and animal origin.This corroborates Famurewa *et al.,* 2012 finding that foods high in carbohydrate has good storage behavior in the tropic regions.

Table 1: Estimated values for fitting models and model evaluation indicators of Tacca Starch at 20 °C Temperature.

Models	Plastic Packaging	(HDP) Packaging	(LDP) Packaging
GAB	k = 0.6120	k = 0.6421	k = 0.6215
	c = 15.0493	c = 33.5940	c = 51.7655
	M_0 = 0.0615	M_0 = 0.0633	M_0 = 0.0726
	RSS= 4.93 x10E-5	RSS= 3.18x10E-5	RSS= 3.71x10E-5
	SEE= 6.07x10E-5	SEE= 4.01x 10E-6	SEE= 6.48x10E-6
	R^2= 0.9939	R^2= 0.9966	R^2= 0.9968
BET	c = 8.995	c= 7.126	c= 15.205
	M_0 = 0.0261	M_0 = 0.0309	M_0 = 0.0350
	RSS= 0.0016	RSS= 0.00259	RSS= 0.0041
	SEE= -0.00746	SEE= -0.01096	SEE= -0.01414
	R^2= 0.8706	R^2= 0.9275	R^2= 0.8287
OSWIN	c = 0.0700	c = 0.0873	c = 0.1015
	n= 0.35	n= 0.2705	n = 0.2402
	RSS= 0.0163	RSS= 4.04x10E-5	RSS = 4.72x 10E-5
	SEE= -0.00327	SEE= 2.65x10E-5	SEE= -3.75x10E-6
	R^2= 0.9849	R^2= 0.9957	R^2= 0.9960
MODIFIED OSWIN	a= 0.0719	a= 0.0857	a= 0.1002
	b= 9.36x10E-5	b= 8x10E-5	b= 6.01x10E-5
	c= 0.3200	c= 0.2705	c= 0.2402
	RSS= 0.0001	RSS= 4.04x10E-5	RSS= 4.72x10E-5
	SEE= 0.000205	SEE=2.64x10E-5	SEE= -3.79x10E-6
	R^2= 0.9876	R^2= 0.9957	R^2= 0.9960
SMITH	c = 0.0349	c = 0.0479	c= 0.0602
	n = -0.0512	n = -0.0508	n = -0.0526
	RSS= 0.00023	RSS= 0.00012	RSS= 0.00012
	SEE= -2.27x10E-9	SEE= -1.55x10E-5	SEE= -4.02x10E-9
	R^2= 0.9713	R^2= 0.9957	R^2= 0.9898
HASLEY	c= 0.00039	c= 0.000142	c= 0.000141
	n= 0.01264	n= 0.00403	n= 0.00353
	RSS = 0.00372	RSS= 0.00594	RSS= 0.00903
	SEE = -0.0163	SEE= -0.0217	SEE= -0.0271
	R^2 = 0.8064	R^2= 0.7747	R^2= 0.7315

HENDERSON	c= 3.77 n= 23.209 RSS= 0.00265 SEE= -0.0138 R^2= 0.8717	c= 0.4569 n= 23.306 RSS= 0.00468 SEE= -0.0190 R^2= 0.8277	c= 0.03754 n= 23.724 RSS= 0.0073 SEE= -0.0238 R^2= 0.7866

Table 2: Estimated values for fitting models and model evaluation indicators of *Tacca* Starch at 30 °C Temperature.

Models	Plastic Packaging	(HDP) Packaging	(LDP) Packaging
GAB	k = 0.8530 c = 12.4357 M_0 = 0.0607 RSS= 0.000789 SEE= 0.006818 R^2= 0.9492	k = 0.9423 c = 12.2588 M_0 = 0.0597 RSS= 0.00719 SEE= 0.0105 R^2= 0.9135	k = 0.7329 c = 25.3079 M_0 = 0.0691 RSS= 0.000185 SEE= 0.001225 R^2= 0.9841
BET	c = 0.5051 M_0 = 0.0257 RSS= 0.000689 SEE= 0.00556 R^2= 0.9537	c = 0.4316 M_0 = 0.02867 RSS= 0.00161 SEE= 0.00924 R^2= 0.9196	c = 0.2394 M_0 = 0.0347 RSS= 0.00418 SEE= 0.01414 R^2= 0.8233
OSWIN	c = 0.7673 n= 0.9278 RSS= 0.00001 SEE= -0.000038 R^2= 0.9999	c = 0.0883 n= 0.2834 RSS= 0.000048 SEE=-0.00004 R^2= 0.9948	c = 0.0991 n = 0.2373 RSS= 0.000066 SEE= -0.0000051 R^2= 0.9941
MODIFIED OSWIN	a= 0.0212 b = -0.061 c = 0.3318 RSS= 0.00091 SEE= 7.49x 10E-13 R^2= 0.8838	a= 0.0838 b= 0.2834 c= 0.2834 RSS= 0.000048 SEE=-0.00004 R^2= 0.9948	a= 0.0991 b= 0.2834 c= 0.2373 RSS= 0.000066 SEE= -0.0000051 R^2= 0.9941
SMITH	c = 0.0212 n = -0.061 RSS= 0.00091 SEE= 7.49x 10E-13 R^2= 0.8838	c= 0.0295 n = -0.0644 RSS= 0.00145 SEE= 2.59x10E-11 R^2= 0.8425	c= 0.0393 n = -0.0685 RSS= 0.7806 SEE= -2.66x10E-11 R^2= 0.7806
HASLEY	c= 0.0212 n= -0.661 RSS = 0.0013 SEE = 7.49x10E-13 R^2 = 0.8838	c = 0.0295 n= -0.0644 RSS= 0.00144 SEE= 2.50x10E-11 R^2= 0.8427	c= 0.0393 n= -0.0685 RSS= 0.00246 SEE= -2.66x10E-11 R^2= 0.7807
HENDERSON	c = 3.5 n= 3.099 RSS= 0.0013 SEE= 7.49x10E-13 R^2= 0.8838	c = 0.02 n= -0.0295 RSS= 0.8425 SEE= 2.59x10E-11 R^2= 0.8425	c= 0.0393 n= -0.0685 RSS= 0.00246 SEE= -2.66x10E-11 R^2= 0.7807

a, b, c, n and k are the model constants; RSS = residual sum of squares; SEE= the standard error of estimate; and R^2 the co-efficient of fit.

Table 3: Estimated values for fitting models and model evaluation indicators of Tacca Starch at 40 °C Temperature.

Models	Plastic Packaging	(HDP) Packaging	(LDP) Packaging
GAB	k = 0.8990	k = 0.9621	k = 0.79215
	c = 10.4593	c = 11.5684	c = 20.2613
	M_0 = 0.0337	M_0 = 0.0444	M_0 = 0.0561
	RSS= 1.6 x10E-5	RSS= 9.70x10E-6	RSS= 3.90x10E-5
	SEE= 2.32x10E-5	SEE= 1.39x 10E-5	SEE= 8.20x10E-6
	R^2= 0.9973	R^2= 0.9987	R^2= 0.9958
BET	c = 2.1729	c = 1.8073	c = 1.5822
	M_0 = 0.0249	M_0 = 0.0276	M_0 = 0.0302
	RSS= 0.000127	RSS= 0.00045	RSS= 0.00209
	SEE= 0.00069	SEE= -0.0047	SEE= -0.0155
	R^2= 0.9884	R^2= 0.9733	R^2= 0.9110
OSWIN	c = 0.0552	c = 0.06954	c = 0.08655
	n= 0.3879	n= 0.3465	n = 0.2703
	RSS= 9.73x10E-5	RSS= 7.2x10E-5	RSS = 5.85x 10E-5
	SEE= 0.000383	SEE=0.000275	SEE= 7.07x10E-5
	R^2= 0.9833	R^2= 0.9909	R^2= 0.9938
MODIFIED OSWIN	a= 0.05392	a= 0.0232	a= 0.0256
	b= -0.1334	b= 0.00116	b= 0.00152
	c= 0.3881	c= 0.3465	c= 0.2702
	RSS= 9.7x10E-5	RSS= 7.2x10E-5	RSS= 5.8x10E-5
	SEE= 0.00038	SEE=0.00027	SEE= 7.08x10E-6
	R^2= 0.9833	R^2= 0.9909	R^2= 0.9938
SMITH	c = 0.0202	c = 0.0300	c= 0.047
	n = -0.0472	n = -0.052	n = -0.0504
	RSS= 0.000169	RSS= 0.00019	RSS= 0.00017
	SEE= -8.13x10E-9	SEE= -2.94x10E-5	SEE= -4.19x10E-9
	R^2= 0.9705	R^2= 0.9754	R^2= 0.9815
HASLEY	c= 0.00373	c= 0.000208	c= 0.000284
	n= 0.0152	n= 0.0069	n= 0.00815
	RSS = 0.00169	RSS= 0.00298	RSS= 0.00596
	SEE = -0.0101	SEE= -0.0143	SEE= -0.0216
	R^2 = 0.8462	R^2= 0.8297	R^2= 0.7654
HENDERSON	c= 1.889	c= 1.234	c= 0.7654
	n= 8.097	n= 7.28	n= 14.765
	RSS= 0.00098	RSS= 0.03745	RSS= 0.00464
	SEE= -0.0080	SEE= -0.0095	SEE= -0.0188
	R^2= 0.9231	R^2= 0.8988	R^2= 0.8232

a, b, c, n and k are the model constants; RSS = residual sum of squares; SEE= the standard error of estimate;and R^2 the co-efficient of fit.

4.0 CONCLUSION AND RECOMMENDATIONS

It can be concluded based on the results of this study that *tacca* starch can best be stored at 40 °C a temperature little above the ambient temperature which are experienced in the tropical regions and GAB model can be best used to predict the storage behavior of tacca starch.Hence there is need for more production and processing of tacca tuber to starch in the tropical regions

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Tacca starch inside the incubator

Tacca starch inside dessicator