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Moisture Sorption Isotherms of *Ogi* Produced with Carrot Pulp

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Abstract: It is important to determine the sorption properties of foods. An enriched product was developed using dried pulp from carrot and dried maize-ogi. Carrot is an important root vegetables rich in bioactive compounds and its pulp contains about 50% nutrients for the supplementation of ogi which is known to be low in nutrient. There is therefore a need to study the product's storage stability. Hence, adsorption equilibrium moisture contents of maize ogi-carrot pulp blends were determined experimentally in relative humidity range of 10-80% and at the temperatures of 30, 35 and 40°C. The experimental procedure used was a standard static gravimetric method with periodically recording of sample mass. The effect of temperatures on adsorption isotherms was found significant and the research has also found that the adsorption isotherms of the ogi blend, exhibited sigmoidal shapes, representing Type II isotherms like most foods. Four sorption isotherm models (Smith, Khun, GAB and BET) were fitted the experimental data at the temperatures of 30, 35 and 40°C. As the equilibrium moisture content decreased with increase in temperature, the GAB model best describes the experimental data for relative humidity range of 10-80% for the adsorption isotherms of *ogi*-carrot pulp blends. M_o, were 2.53, 2.14 and 0.46 g/10 g db (GAB) and 2.31, 2.29 and 1.51 g/10 g db (BET) at 30, 35 and 40°C respectively.

Keywords: Sorption, Adsorption, Water Activity, Equilibrium Moisture Content

1. Introduction

Group of products which are obtained from cereals processed with or without undergoing fermentation are porridges. Porridges are fully made up of starch and water and some amounts of amino acid, depending on the cereal type. Some groups of porridges that are well known are obtained from guinea corn (Sorghum spp), millet (Pennisetum americum) and maize (Zea mays). Porridges are usualy stirred in hot water and always in semi-solid and solid forms. *Ogi* is a Yoruba name but in most state of Nigeria, it is referred to maize pap. *Ogi* is widely consumed with or without accompaniment, as weaning, breakfast and dinner food [19, 26]. Due to its soft texture, 'ogi' is used to nurture the sick and the convalescent to good health. It is a popular food among the elderly and a convenient food for categories of people including nursing mothers.

In some communities, ogi can be mixed with water and taken by people having frequent stooling [20, 26].

For effectiveness of the processing techniques and nutritional contribution of ogi, several approaches were made earlier, namely diet diversification, supplementation of ogi with essential micronutrients; vitamin and mineral and some protein rich foods [17] or enrichment and optimization of processing conditions [11] to reduce losses of nutrient in cereals, such as maize especially during milling because the nutrients are contained in the hull and germ of the cereals. Fortification strategies include addition of micronutrients such as iron, zinc and Vitamin A to food [19]. In this study, the restoration of some lost nutrients was done by supplementing maize ogi with carrot pulp; a waste obtained from carrot juice done by pulping.

Carrot (Daucus carota) has abundant nutrients such as the precursor of Vitamin A and some amounts of minerals. It has various colour and texture especially when freshly harvested. It is also high in minerals such as calcium, Copper, Magnessium, folic acid, Phosphorus. It is regarded as a healthy food item because of its high vitamins and fibre content [10, 25]. Thus, the chemical composition of carrots makes it important in Nutrition.

Pulp is a slurry expressed from carrot by blending and extracting the juice of carrot. The extraction of the juice is done by chopping the carrot, disintegrating and passing it through a sieve and the slurry obtained is regarded as the carrot pulp which is usually discarded by most processors since it is considered as waste [1] Meanwhile, it contains about 30% nutrient of carrot.

It is paramount to improve drying and storage processes of various foods for good quality [22]. Food may experiences several unacceptable changes during these processes. The major factors that can be responsible for these is moisture content of food and storage temperature. Sorption characteristics of foods are crucial for design, modeling and optimization of many processes [15, 21, 5, 16].

Many investigators such as [8] who reviewed 23 sorption equations have developed mathematical equations, theoretical, semitheoretical and empirical to describe the sorption isotherms of food. The current information on sorption isotherms of ogi and its by-products such as ogi-carrot pulp is rather scarce This study was undertaken for the determination of sorption characteristics of ogi blends produced from maize and carrot pulp.

2. Materials and Methods

2.1. Sample Preparation

Carrot and white maize variety used for this study were purchased locally from fruit and vegetable suppliers.

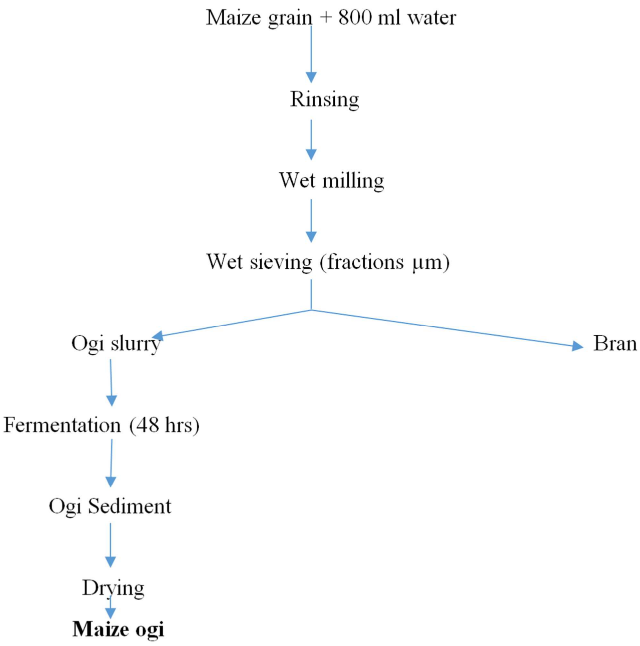
Maize- *Ogi* was prepared using the wet-milling process described by [1]. Ogi was soaked, wet milled, sieved and allowed to have sediment which was dried and milled into powder [3] as shown in Figure 1.

2.3. Preparation of Carrot Pulp

Figure 2 describes the production of carrot pulp from fresh carrot. The carrots were cleaned and pulp was obtained after extracting the juice using a juice extractor. The pulp was dried and milled into powder as described by [1].

2.4. Supplementation of Maize-ogi With Carrot Pulp

The maize ogi flour and carrot pulp flour were combined as 90:10; 80:20; 70:30, 60: 40 and 50: 50.



Source: [1]

Figure 1. *Maize ogi Production.*

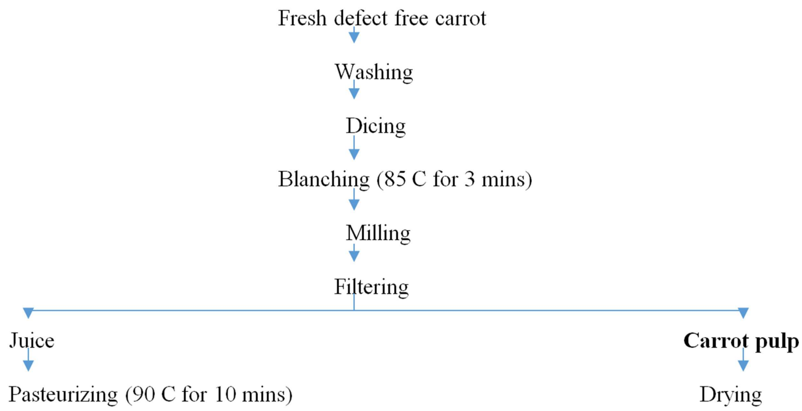


Figure 2. *Modified method for the preparation of Carrot pulp [4, 1].*

2.5. Sorption Isotherm

Sorption isotherm of ogi blends were determined using gravimetric method standardized [28]. About 250 ml of each of the prepared relative humidity solution was transferred to a labelled flat bottom glass dessicator (250 mm diameter and 350 mm deep in base) with a perforated porcelain plate. Heavy oil was used to exclude air entering through the edge. The heavy oil was specifically used to prevent it from flowing to the sample.

Wink's weight equilibrium method was adopted for obtaining the EMC of samples at 30, 35, 40°C. Samples (2g) were duplicated samples and placed inside sorption jars at eight atmospheric conditions indicated by using water activity (a_w= 0.1- 0.8). An incubator was used to monitor the temperatures and the samples were equilibrated for 96 hrs or more until constant weight was achieved. EMC was calculated using the original weights and the known changes in weight.

Table 1. *Sorption Isotherm Models.*

Model	Equation
Oswin (1946)	$M_w = C\left[\frac{a_w}{1-a_w}\right]^n$
Halsey (1948)	$M_w = \{\frac{-a}{ln\, a_w}\}^{1/b}$
BET	$M_w = \frac{a\, b\, a_w}{(1-a_w)[1+(b-1)a_w]}$
GAB (Van den Berg, 1984)	$M_w = \frac{a\, b\, c\, a_w}{(1-(ca_w)(1-c\, a_w+b\, c\, a_w)}$
Peleg	$M_w = a\,(a_w)^b + c\,(a_w)^d$
Smith (1947)	$M_w = (a+b)\ln(1-a_w)$

2.6. Model Development

Data obtained were fitted to each of the models listed in Table 1 and the constants of the models were estimated.

3. Results and Discussion

The data for the sorption characteristics of the blends at three different temperatures are given in table 2 and graphically interpreted as shown in figure 3 which gave sigmoid shapes as expected. At lower temperature, higher EMC was observed which could be due to increase in temperature this is in accordance with results obtained for food materials low in sugar content [14, 6, 23].

3.1. Fitting of Sorption Data to Various Isotherm Models

Linear and non-linear squares regression analysis are presented in Table 2. They showed differences with temperature. This agrees with other studies [2]. The temperature dependence of the GAB monolayer moisture content, similar to that shown by [2, 18] and [13] would also corroborate this evidence. It was noticed that the GAB monolayer moisture contents decreased as temperature increased. The reason is because there is relationship between sorption active sites and temperature induced changes [12, 27].

The predictive performance of each isotherm model in describing the sorption behaviours of the maize ogi and carrot pulp blends as indicated by E% and coefficient of determination, R^2 is presented in Table 2. It can be observed that only the Oswin model and to a lesser extent the Kuhn model fit the data while the GAB and BET models provide the best fit the maize ogi and carrot pulp blends. At higher moisture content, the predictive ability of the models was significantly lowered as also observed by [9].

The order of suitability provided by GAB and BET models to the data for the maize ogi and carrot pulp blends, however disagreed with that reported by [29] Oswin model gave the best fit for vegetables. The differences in the order of suitability of these models for the vegetables could be ascribed to differences in chemical compositions. Myhara et al. (1998) reported sorption is a function of chemical and physical composition of foods.

Food flours (the blends) studied fell within ranges found for other foods [12]. The estimated monolayer moisture contents from BET model were usually slightly less than those obtained from the GAB model. This observation agrees with results obtained.

Since all the C values obtained are less than 4 as shown in table 2, it can be concluded that the estimated monolayer values form the BET model are not reliable. The mean relative percentage modulus (E %) values are less than 10 for GAB model. This together with the coefficients of correlation, indicates that the two models fitted the moisture adsorption data of the maize ogi and carrot pulp blends studied reasonably well [7]. The estimated C values from the two models are not comparable.

The study revealed that BET equation could be applied for the practical safe region of moisture levels in foodstuffs.

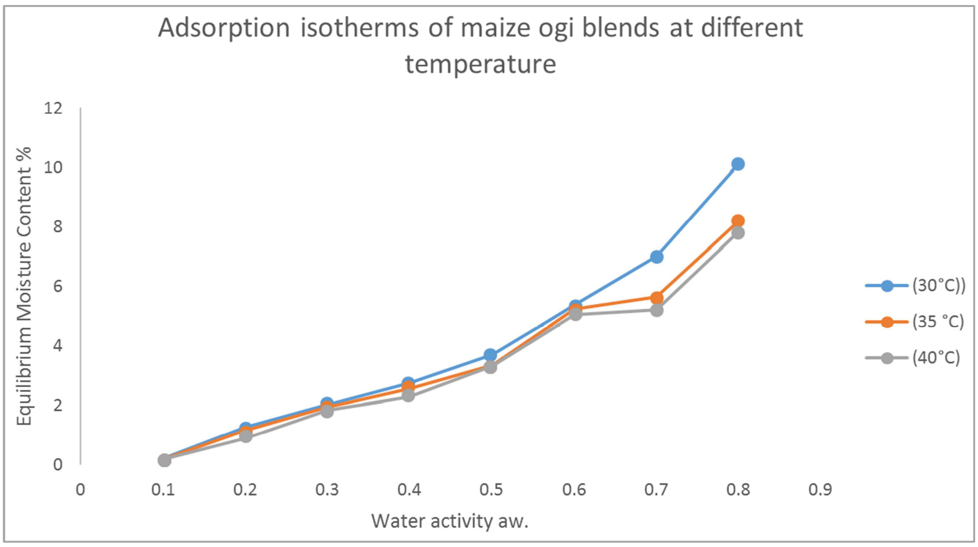


Figure 3. *Adsorption Isotherms of Maize ogi-carrot pulp blends at temperature 30, 35 and 40°C.*

Table 2. *Experimental equilibrium moisture contents of ogi-carrot pulp blends at different temperature and activity (a_w 0.1-0.8).*

Water activity (a_w)	RH (10%- 80%)	EMC at 30°C	35°C	40°C
0.1	10	0.21	0.18	0.18
0.2	20	1.26	1.15	0.90
0.3	30	2.03	1.95	1.83
0.4	40	2.76	2.55	2.28
0.5	50	3.69	3.35	3.33
0.6	60	5.38	5.23	5.05
0.7	70	6.98	5.65	5.20
0.8	80	10.13	8.18	7.83

EMC- Equilibrium Moisture Content.

Table 3. *Parameter values of the models fitted to the ogi blend sorption isotherm in the water activity 0.1- 0.8.*

Model	Temperature (C)	C	K	X_m (Kgkg^{-1} dry solid)	E (%)	R^2
OSWIN	30	3.07	0.75	-	3.00	0.91
	35	5.70	1.33	-	15.82	0.78
	40	3.71	0.7501	-	7.23	0.73
KUHN	30	-0.279	2.577	-	34.34	0.66
	35	-0.439	3.761	-	45.00	0.44
	40	-0.122	1.533	-	33.00	0.75
BET	30	3.581	-	2.31	76.77	0.92
	35	2.921	-	2.299	79.85	0.96
	40	2.845	-	1.514	27.75	0.96
GAB	30	2.492	1.03	2.54	1.7	0.91
	35	2.562	1.099	2.14	1.97	0.90
	40	1.682	1.746	0.457	7.28	0.99

E (%)- Mean relative percent deviation modulus; R^2- coefficient of determination; X_m- Monolayer moisture content (Kgkg^{-1} dry solid) K- constant; C- Empirical constant.

3.2. Monolayer Moisture Content

M_o, were 2.53, 2.14 and 0.46 g/10 g db (GAB) and 2.31, 2.29 and 1.51 g/10 g db (BET) at 30, 35 and 40°C respectively. X_m were obtained using the GAB and BET models. Values obtained in this study are lower than the ones for yellow corn meal by [16] and yellow dent corn by [24].

The results also showed that X_m decreased with increase in temperature as shown below:

$$M_o = -0.208x + 8.993; R^2 = 0.887 \text{ (GAB)} \quad (1)$$

$$M_o = -0.08x + 4.836; R^2 = 0.768 \text{ (BET)} \quad (2)$$

These differences could be attributed to the different working conditions such as method of drying, variety differences in the products and the fortification process, in the case of the blends. For the blends, the particle size could also have a great impact.

4. Conclusions

The highly perishable carrot and maize ogi were successfully processed into a more stable form without change in its quality. This work has also revealed the utilization of traditional enriched ogi. The research has also found that the adsorption isotherms of the ogi blend, exhibited sigmoidal shapes, representing Type II isotherms like most foods. However, temperature influenced the adsorption isotherms, with the EMC increasing with decreasing temperature at the same water activity.

The sorption behavior of the blends showed the GAB and BET are adequate in describing the sorption isotherm of the products. The results suggest that the sorption of the blend may be useful in determining the behavior of the product at different storage and processing conditions.

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