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SORPTION ISOTHERM STUDY OF SOY-ENRICHED "IPEKERE AGBADO" (A NIGERIAN TRADITIONAL MAIZE SNACK)

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ABSTRACT

"Ipekere agbado" is a maize-based snack that is consumed in the Western region of Nigeria. "Ipekere agbado" was produced from composite of maize and soy flour in ratio 100:0, 90:10, 80:20 and 70:30 by mixing appropriate amount of warm water, ground pepper, onion and salt, and the dough moulded by hand and fried in vegetable oil. They were subjected to static sorption isotherm study to determine equilibrium moisture content (Me) using salt solutions of CH_3COOK, $MgCl_2$, K_2CO_3, KI, NaCl, and KNO_3 which provide wide range of relative humidities ranging from 23% to 92% under the ambient temperature of 28±2°C. Samples were weighed at three days intervals until three consecutive weighing were obtained. The equilibrium moisture content (Me) were determined and used to draw the sorption isotherm curve from where the monolayer moisture contents for BET and GAB were determined. The curves obtained exhibited type II and V sigmoid shapes, with an increase in equilibrium moisture content as water activity increased at constant temperature. "Ipekere agbado" samples from maize flour only and those produced from 70% maize flour and 30% soy flour were best predictions from moisture sorption isotherm by BET and GAB equation. The monolayer moisture content, M_o obtained with BET equation in range of 0.022 to 0.057 were lower than monolayer moisture content obtained with GAB equation in range of 0.025 to 0.079.

Keywords: "Ipekere agbado"; Equilibrium; Sorption isotherm; BET; GAB equation; Monolayer moisture content

INTRODUCTION

During storage, the moisture content of stored products is altered by prevailing temperature and relative humidity of the environment. Water activity has been pointed out to be of a great importance in influencing biochemical activities which result in degradation of food quality (Rockland and Nishi, 1980). The effects of dynamic process of water migration during storage of crops or crop products need considerable attention for optimum storage qualities.

Knowledge of sorption isotherm properties of food is important for determining food storage stability, which depends majorly on the water activity of product (Pascual and Clara, 1999).

Moisture sorption isotherms are fundamental characteristics of food materials essential for the dehydration process, and related to almost every aspect of the storage stability of dried products. Moisture sorption isotherms give information about water activity, which is intimately related to deteriorative reactions in foods. They also provide an easy way to evaluate physical, chemical, and microbiological parameters suitable for the determination of food stability (Labuza et al., 1970; Mizrahi and Karel, 1977; Loncin et al., 1968).

Igbeka et al., 1975 stated that under a given vapour pressure of water (relative humidity or water activity) in the surrounding; a food attains a moisture content known as an equilibrium moisture content (EMC). The EMC is the moisture content that can be achieved under a given set of conditions of temperature and humidity (Labuza, 1970; Onayemi and Oluwamukomi, 1986). A plot of the EMC of a product against the vapour pressure or relative humidity of the air in equilibrium with the food at a particular temperature is called moisture sorption isotherm. The curve is called isotherm since measurement with different humidity are: Adsorption isotherm, that is made placing a completely dry food samples into various atmospheres of increasing relative humidity and measuring the weight gain due to water to establish equilibrium (Labuza, 1968).

Igbeka et al. (1975) and Onayemi and Oluwamukomi (1986) stated that the equation that describe the shape of the moisture isotherm and correlate the equilibrium relationship between the amounts of water absorbed and water activity could be useful in prediction of the Shelf life expectancy of a product, rate and extent of drying during dehydration, the best moisture level for maximum storage stability, packaging requirement and whether the product will support or inhibit microbial growth.

This research study was aimed to determine the sorption isotherm of soy-enriched "Ipekere agbado" samples at ambient temperature.

MATERIALS AND METHODS

Collection of materials

Dried maize grain, soybeans, pepper, onion and salt were purchased from a neighborhood market, Akure, Ondo State, Nigeria.

Production of soy flour

The soybeans was weighed, sorted, washed and boiled in water for 100^{o}C. It was dehulled manually, oven dried at 55 ^{o}C for 16 hrs and milled in disc attrition mill to obtained soy flour.

Production of Soy-enriched 'Ipekere agbado'

Maize grains was weighed, sorted, washed and steeped in warm water for 24 hrs for fermentation to take place. It was sun dried and dry milled with disc attrition mill and obtained maize flour. The maize and soy flour were blended in varying proportions as follow; 90:10, 80:20 and 70:30 respectively. The composite was mixed with appropriate quantity of hot water, blend pepper and onion, and table salt were mixed thoroughly and produced dough. The dough was cut flat steel cutter and fried in hot vegetable oil.

Equilibrium moisture content (Me) of 'Ipekere agbado' was determined using the static method, which is based on the use of saturated salt solutions to maintain constant water activity of samples until equilibrium between room conditions and food sample is reached (Greenspan, 1977). Salt solutions used were CH_3COOK, $MgCl_2$, K_2CO_3, KI, NaCl, and KNO_3. This group of salts provides a wide range of relative humidity, ranging from 23% to 92% (Rockland, 1969; Labuza, 1985). To determine sorption isotherms of 'Ipekere agbado', the analysis was conducted at ambient temperature, 28±2^{o}C. The "Ipekere agbado" samples were weighed and were kept on a flat perforated ceramic plate inside desiccators containing saturated salt solutions, hermetically closed and kept at ambient temperature.Samples were daily weighed until three consecutive weighing were constant using a digital balance (model mettle PE1600, Mettler Instrument Corporation, Greifensee, Zurich, Switzerland). Subsequently, the moisture contents of these samples were determined, obtaining the equilibrium moisture content for each treatment condition.

Determination of Sorption Isotherm curve

The constant mass obtained for each "Ipekere agbado" samples after sorption isotherm experiments in different water activities was used to calculate equilibrium moisture content (MC_{db} or EMC) using equation (1) by Paul and Heldman (2009):

$$MC_{db} = \frac{Mass\ of\ water}{Mass\ of\ dried\ sample} \quad (1)$$

To predict the sorption isotherm curve of the "Ipekere agabdo" samples, EMC (% d.b) were plotted against water activities using Microsoft excel package 2006 version.

Determination of monolayer moisture content using BET equation

The experimental values of ERH and EMC were used to find the best fit line of BET equation for each "Ipekere agabdo" samples. A simplified form of BET equation (2) is written as:

$$M_e = \frac{AC\ a_w}{(1-a_w)(1-a_w+C(a_w))} \quad (2)$$

and the linearized form is written as:

$$\frac{a_w(1-a_w)}{Me} = \frac{1}{Mo} + \frac{(C-1)}{MoC} a_w \quad (3)$$

$\frac{a_w(1-a_w)}{Me}$ was plotted against water activities a_w to obtain best fit line of BET equation for each sample.

Where,

a_w = relative humidity (db);

m_o = monolayer moisture content (mg water/g dry flour);

A, *C* = model constants;

M_e = equilibrium moisture content value (%).

The intercept and the slope of the curve obtained were used to determine the monolayer values, M_o of the "Ipekere agbado" samples according to Iglesias and Chirife (1976)

The M_o and the constant C were calculated by solving the slope and intercept equations simultaneously. These were calculated as shown in equations (4):

$$M_o = \frac{C-1}{SC} \times 100 \quad (4)$$

$$C = \frac{(S+1)}{I} \quad (5)$$

where

M_o = monolayer moisture content;

S = slope of the graph;

I = intercept of the graph on the y axis;

C = product constant.

Determination of monolayer moisture content using GAB equation

The GAB equation can be expressed as follows (Van de Berg, 1984; Labuza et al., 1985):

$$\mathbf{M_e} = \frac{CKMo\,a_w}{(1-Ka_w)(1-Ka_w+CKa_w)}$$

The three parameters of GAB values of C, K and Mo were derived from the second order polynomial form which was solved by multi-linear regression analysis to obtain α, β, γ and r^2 (Jouppila and Roos, 1997; Abramovic and Klofutar, 2002; Oluwamukomi, 2009):

$$\frac{a_w}{Me} = \frac{K}{Mo(1/C-1)} a_w^2 + \frac{(C-2)}{MoC} a_w + \frac{1}{MoCK}$$ in second order polynomial form

$$\frac{a_w}{Me} = \alpha a_w^2 + \beta a_w + \gamma \quad (6)$$

$$\alpha = \frac{K}{Mo(1/C-1)} \quad (7)$$

$$\beta = \frac{(C-2)}{MoC} \quad (8)$$

$$\gamma = \frac{1}{MoCK} \quad (9)$$

Where

K and C=constants

aw = water activity

Mo = GAB monolayer moisture

M_e = dry based moisture content

The values of parameters α, β and γ were obtained through the following relations:

$$M_o = \frac{1}{\sqrt{\beta^2 - 4\alpha\gamma}} \qquad (10)$$

$$C = \frac{2\sqrt{\beta^2 - 4\alpha\gamma}}{-\beta + \sqrt{\beta} - 4\alpha\gamma} \qquad (11)$$

$$K = \frac{-\beta + \sqrt{\beta^2} - 4\alpha\gamma}{2\alpha\gamma} \qquad (12)$$

Mo is the monolayer moisture content, c is a constant related to thermal effects and k is the constant related to the properties of multilayer water molecules with respect to the bulk liquid. The quality of fitness of the GAB model were evaluated by calculating

Correlation Coefficient (r^2) (Akanbi et al., 2006)

RESULTS AND DISCUSSION

Determination of sorption isotherm

The moisture isotherm values of fried 'Ipekere agbado' were obtained and presented in Table 1 and sorption isotherm for "Ipekere agbado" samples presented in Figure 1

The monolayer moisture content values and the product constants K and C in GAB and BET equation were obtained and showed in Table 2 and Table 3.

Moisture adsorption isotherm of 'Ipekere agbado' (maize snack)

The adsorption isotherm of FIA 24, SEI 90/10, SEI 80/20 and SEI 70/30 as shown in the figure were sigmoid in shape and of Type II and V according to the classification of Brunauer et al. (1940). The equilibrium moisture content (% d.b) at a constant temperature increases with water activity that is consistent with the theory of physical adsorption (Iglesias et al., 1975). These results agreed also with the findings of a number of investigators on other crops such as rice, sugar beet, corn and wheat (Becker and Sallans, 1956; Hall and Rodriguez-Arias, 1958; Iglesias et al., 1975). Sample FIA 24 exhibited highest equilibrium moisture content. Presumably, the differences in level of soy flour substitution are responsible for different water sorption behaviour of the sample.

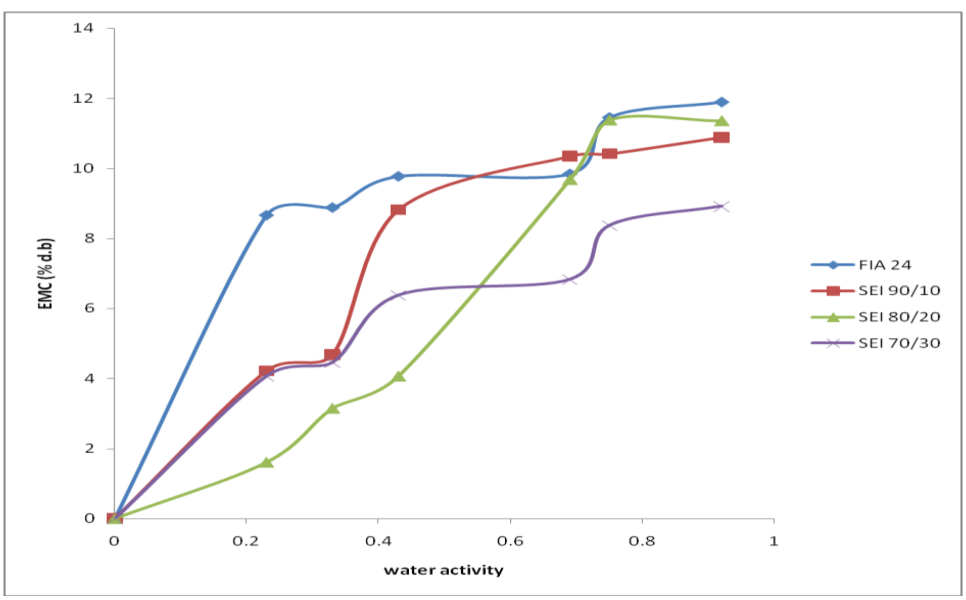

Figure 1: Moisture sorption isotherm of "Ipekere agbado" samples at 28 ± 2 °C

Table 1: Equilibrium moisture content (% d. b)

	%ERH					
Sample	23%	33%	43%	69%	75%	92%
FIA 24	8.66	8.88	9.77	9.84	11.45	11.89
SEI 90/10	4.22	4.69	8.82	10.35	10.42	10.89
SEI 80/20	1.61	3.15	4.07	9.68	11.38	11.36
SEI 70/30	4.01	4.46	6.38	6.83	8.37	8.92

Fitting of BET and GAB sorption model to experimental sorption data

The EMC values increased with increase in ERH at constant temperature. At 23% ERH, the EMC of FIA24, SEI 90/10, SEI 80/20 and SEI 70/30 were 8.66%, 4.22%, 1.61% and 4.07% respectively while at 92% ERH, the EMC of FIA24, SEI 90/10, SEI 80/20 and SEI 70/30 were 11.89%, 10.89%, 11.36% and 8.92% respectively.

Similar trends have been reported in literature for many food according to Durakova and Menkov (2005); Al Muhtaseb et al., (2002); Raji and Ojediran (2011).

In order to calculate the M_o at a constant temperature, 'Ipekere agabdo' samples with different moisture content and at different relative humidity were used. The plot of the best fit line of the BET and GAB equation was selected by using linear regression analysis and straight line equation was generated for BET and second order polynomial was generated for GAB. The monolayer moisture content obtained for BET was consistently lower than result obtained for monolayer moisture content in GAB.

The difference in Mo values of "Ipekere agbado" samples may be as a result of varying proportion of soy flour substitution. The sample FIA 24 (un-enriched sample) has the highest Mo value compared to soy enriched samples. This finding agreed with report of Oluwamukomi (2009) on M_o values of adsorption modeling of soy-melon-enriched and un-enriched 'garri' using GAB equation.

Table 2: BET Parameters

Parameters	FIA 24	SEI 90/10	SEI 80/20	SEI 70/30
C	-86.45	25.54	16.85	76.13
Mo	0.057	0.042	0.022	0.034
r^2	0.990	0.830	0.793	0.971

Table 3: GAB Parameters

Parameters	FIA 24	SEI 90/10	SEI 80/20	SEI 70/30
α	-4.65	-10.83	-34.83	-13.97
β	12.71	17.23	34.61	23.09
γ	-0.018	0.872	2.703	0.425
Mo	0.079	0.055	0.025	0.042
C	1.520	5.293	17.985	4.799
K	63.14	-18.20	-34.82	-25.08
r^2	0.991	0.807	0.485	0.951

CONCLUSION

Moisture sorption isotherm curve of samples (FIA 24, SEI 90/10, SEI 80/20 and SEI 70/30) at relative humidity ranging from 23% to 92% at constant temperature exhibited S-shaped sorption isotherm. Sample FIA 24 and SEI 70/30 were best predicted for moisture equilibrium by BET and GAB equation. The monolayer moisture content obtained for BET was consistently lower than result obtained for monolayer moisture content in GAB. In both cases the monolayer moisture content decreased with increasing level of soy flour enrichment

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