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Moisture sorption isotherm characteristics of breadfruit flour as influenced by pretreatments

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Abstract
In this study the effect of pretreatments (pH-3 buffer, microwave radiation and disodium ethylene diamine tetra acetic acid (EDTA)) on the sorption isotherm characteristics of breadfruit flour was investigated. Moisture sorption isotherms of treated breadfruit flours and an untreated flour (control) were determined within a range of water activities 0.1 – 0.8 at 30ºC using the static gravimetric method. Data generated were fitted into GAB and BET model equations. Sorption isotherms of the flours had sigmoid shape. GAB and BET monolayer moisture contents at 30ºC for the samples were 3.79 and 2.82 g/100gdb (control), 3.67 and 3.01 g/100gdb (pH-3 buffer), 3.30 and 2.69 g/100gdb (microwave radiation) and 3.80 and 2.94 g/100gdb (EDTA) respectively. Monolayer moisture contents of the flour samples were lower than the maximum value of 10.00 g/100g (db) recommended for shelf stability. Microwave radiation treated flour had the least monolayer moisture contents. Mean relative deviation modulus (%E) values of the breadfruit flours were in the range 9.07% - 12.49% for GAB model and 14.09% - 20.66% for BET model. Pretreatment affected the moisture sorption characteristics of breadfruit flour and GAB model described the sorption characteristics of breadfruit flour at 30ºC better than BET model.

Keywords: breadfruit flour, pretreatment, water activity, monolayer moisture content, isotherm model equations

Introduction

Relative humidity, water activity and moisture absorption during storage determine flour reactivity to enzyme and the rate of mouldiness, sogginess, staleness, rancidity and cakiness during processing, storage, distribution and marketing (Ajiboye, 2013; Menkov and Durakova, 2007) [5, 20]. The relationship between these parameters, which is called moisture sorption isotherm, is very important in food especially during storage because it can be used to predict the quality, stability and shelf life of food materials (Andrade *et al*., 2011; Damodaran *et al*., 2008) [9, 15]. It provides information on the optimum moisture content to be achieved during flour production and the selection of packaging materials that will ensure protection against quality deterioration during storage. A major parameter in sorption isotherm is monolayer value which indicates the moisture content that ensures good storage stability of dehydrated products (Osundahunsi *et al*., 2014) [26]. Moisture sorption characteristics of food products are continuously investigated because they affect the storage stability of dried products (Al-Muhtaseb *et al*., 2002) [7].

Breadfruit is a good source of food because of its high calorific value, a moderate glycemic index and appreciable quantity of both macronutrients and micronutrients such as vitamins and minerals. The fruit, which is consumed unripe, is a starchy fruit with equal or better protein and carbohydrate contents than tropical crops like cassava and sweet potato (Oulai *et al*., 2014) [27]. Breadfruit, which is used at the matured unripe stage, deteriorates in about 3-5 days after harvesting (Worrell *et al*., 2002) [30]. One method of preserving breadfruit is processing into flour; the flour is used for production of various foods by reconstituting in hot or cold water according to processing requirement. Research attention is given to the utilization of breadfruit flour especially its use as a component of composite flours. Breadfruit flour is mixed with flours from other crops especially wheat and used to produce food products such as bread, biscuit, instant pounded yam product and dumpling dough (Adebowale *et al*., 2008; Ajani *et al*., 2012; Arinola and Omowaiye-Taiwo, 2020; Olaoye and Onilude, 2008; Olaoye *et al*., 2007) [2, 4, 12, 23, 24]. However, the aspect of sorption isotherm of the flour, which is important to its storage, has not been addressed.

Breadfruit has been pretreated during production of breadfruit flour to eliminate undesirable changes that reduce the quality of the flour during storage (Arinola and Akingbala, 2018) [11]. The pretreatment affects both the starch hydrolyzing enzyme inherent in breadfruit and the macromolecules component of the flour especially starch and protein. Such effect could alter the moisture sorption isotherm pattern of the flour which ultimately affects the critical monolayer moisture content. Study of moisture sorption of breadfruit flour is therefore important to its storage properties and it will provide useful information for those interested in production, marketing and application of the flour in food formulations. However, there is scanty information on the sorption characteristics of breadfruit flour. The objectives of this work were to evaluate the effect of pretreatments on the moisture sorption characteristics of breadfruit flour and to determine the suitability of two commonly used models, Guggernheim-Anderson-de Boer (GAB) and Brunauer-Emmett-Teller (BET) models, in predicting the moisture sorption isotherm of the flour at the temperature studied.

Materials and Methods

Production and Pretreatment of breadfruit flours

Matured unripe breadfruits, sourced from Ile-Ife, Osun state, Nigeria, were subjected to three different pretreatments (pH-3 buffer, microwave radiation and disodium ethylene diamine tetra acetic acid (EDTA) and a control sample (untreated breadfruit flour). Breadfruits were cleaned in water to get rid of adhering soil, latex and dirt. The fruits were peeled, cored and the pulp was cut into pieces with stainless kitchen knife. Breadfruit pieces were divided into four portions; the first untreated portion was used as control. Second portion was steeped in sodium acetate pH-3 buffer solution for 40 minutes. Third portion was exposed to microwave radiation in a Samsung microwave oven (ME731K, 2450 MHz, 800W; Samsung Electronics Co. Ltd., USA) for 40 seconds. Fourth portion was steeped in disodium ethylene diamine tetra acetic acid solution of 10 mM concentration for 30 minutes. After the treatment, each set of treated breadfruit pieces and the untreated set were dried separately in Hinotek hot air oven (DHG 9030A; Hinotek Group Ltd., China) at 80 ^oC for 9 hours. Dried breadfruit pieces were milled in a hammer mill; the flour obtained was sieved through 0.5 mm screen mesh, packaged in high density polyethylene.

Determination of moisture sorption isotherm of breadfruit flours

The static gravimetric method was used to evaluate the sorption isotherm. Briefly, various concentrations of sulphuric acid solution were utilized to provide relative humidity environment which ranged from 10 – 80% (equivalent to water activity 0.1 – 0.8) inside eight well labeled desiccators. Weighed petri dishes containing 3 g of each sample were placed inside the desiccators and the desiccators were placed in a temperature controlled cabinet at constant temperature of 30±0.20^{o}C. These petri dishes were weighed at intervals of 3 days until constant weights (±0.001 g) were observed after three consecutive measurements when the flour samples were assumed to have reached equilibrium. Time to reach equilibrium ranged from 21 – 27 days depending on relative humidity in each of the desiccators, samples in desiccators of lower water activities took longer time to reach equilibrium. After attainment of equilibrium, AOAC (2005) [10] method was used to evaluate moisture content of each flour sample; the value obtained was referred to as experimental equilibrium moisture content (M_{exp}). The moisture isotherm plot was obtained from the graph of equilibrium moisture content of each sample against water activity.

Sorption model equations and data analysis

Two widely recommended isotherm equations, the Guggernheim-Anderson-de Boer (GAB) equation and the Brunauer-Emmett-Teller (BET) equation, were fitted with the experimental equilibrium data to verify their adequacy to describe the sorption isotherm of breadfruit flour.

Guggernheim-Anderson-de Boer (GAB) model equation

GAB equation (1.0), which relates moisture content with water activity, was expressed as follows:

$$Me = \frac{C * K * Mo * \mathrm{aw}}{(1 - K * \mathrm{aw})(1 - K * \mathrm{aw} + C * K * \mathrm{aw})} \quad \ldots\ldots\ldots\ldots \quad (1.0)$$

a_w: water activity
Me: equilibrium moisture value (g/100g)
Mo: monolayer moisturevalue (g/100g)
C and K: constants

A plot of a_w/Me against a_w (Fig 1 - 4) for each sample was used to determine the coefficients of the parabolic equation (1.1) using Microsoft excel software of Microsoft Office 2007

$$\frac{\mathrm{aw}}{Me} = Q1 + Q2 * \mathrm{aw} + Q3 * \mathrm{aw} \quad (1.1)$$

The values of parameters Q1, Q2 and Q3 obtained from parabolic equation (1.1) were used to evaluate GAB parameters of K, C and Mo, using the following equations

$$K = \frac{-Q2 \pm \sqrt{Q2^2 - 4 * Q1 * Q3}}{2 * Q1} \quad (1.2)$$

$$C = 2 + \frac{Q2}{Q1 * K} \quad (1.3)$$

$$Mo = \frac{1}{Q1 * K * C} \quad \ldots\ldots \quad (1.4)$$

GAB constants K, C and monolayer moisture content (Mo) obtained from equation 1.2, 1.3 and 1.4 respectively were fitted into GAB equation (1.0) and the equation was used to obtain predicted equilibrium moisture value (GAB M_{pre}) of the samples over water activity range used in this study.

Brunauer-Emmett-Teller (BET) model equation

BET equation (2.0), which describes moisture content in relation with water activity, was expressed as follows:

$$Me = \frac{Mo * C * \mathrm{aw}}{(1 - \mathrm{aw})(1 + (C - 1)\mathrm{aw})} \quad \ldots\ldots \quad (2.0)$$

This equation can also be transformed to equation 2.1 as shown below

$$\frac{\mathrm{aw}}{Me(1 - \mathrm{aw})} = \frac{1}{Mo * C} + \frac{C - 1}{Mo * C}\mathrm{aw} \quad \ldots\ldots \quad (2.1)$$

a_w : water activity
Me: equilibrium moisture value (g/100g)
Mo: monolayer moisturevalue (g/100g)
C: constants

A plot of $\frac{\mathrm{aw}}{Me(1-\mathrm{aw})}$ against a_w for each sample (Figs 5-8) gave intercept and slope values which were used to obtained BET parameters of Mo and C through the equations 2.2 and 2.3

Intercept of the graph = $\frac{1}{Mo * C}$

Slope of the graph = $\frac{C-1}{Mo * C}$

$$Mo = \frac{1}{(\text{Intercept}) + (\text{slope})} \quad \ldots \quad (2.2)$$

$$C = \frac{1}{1 - (\text{slope} * \text{Mo})} \quad \ldots \quad (2.3)$$

BET monolayer moisture content (M_o) and constants C obtained from equation 2.2 and 2.3 respectively were fitted into BET equation (2.0) and the equation was used to obtain predicted equilibrium moisture value (BET M_{pre}) of the samples over the water activity range used in this study.

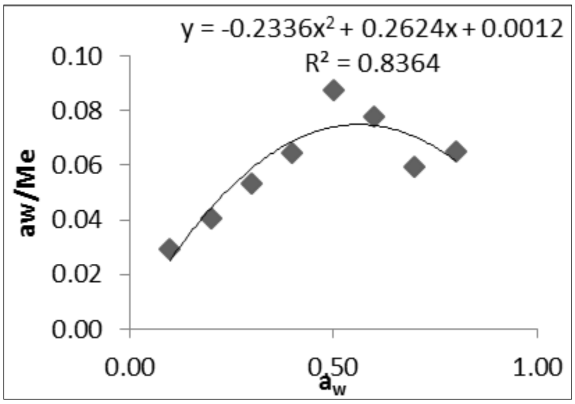

Fig 1: GAB model parabolic plot of untreated breadfruit flour

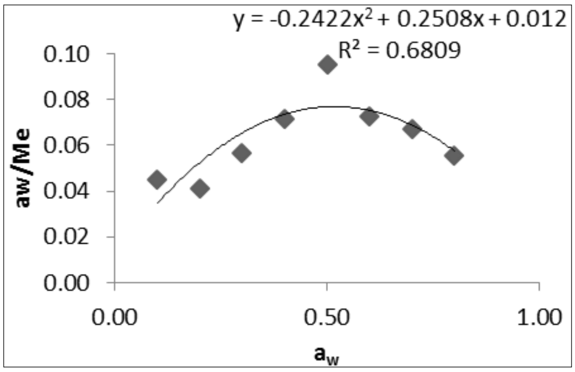

Fig 2: GAB model parabolic plot of pH-3 buffer treated breadfruit flour

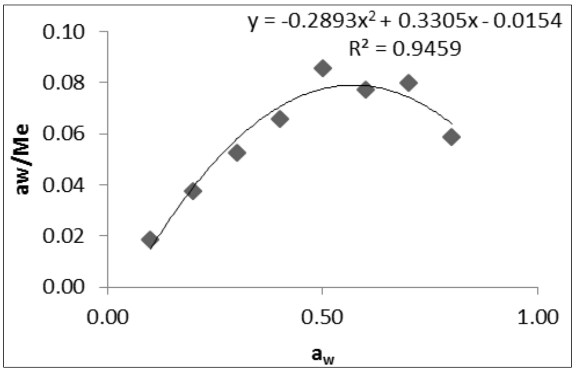

Fig 3: GAB model parabolic plot of microwave radiation treated breadfruit flour

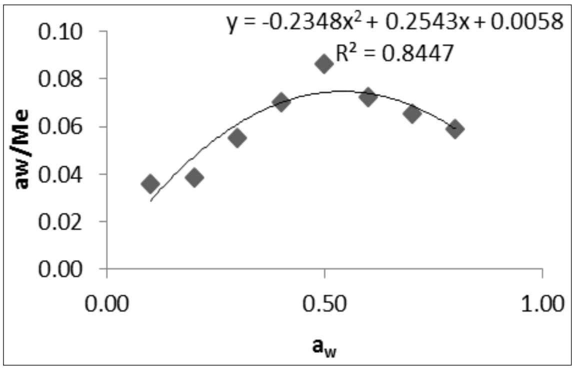

Fig 4: GAB model parabolic plot of EDTA treated breadfruit flour

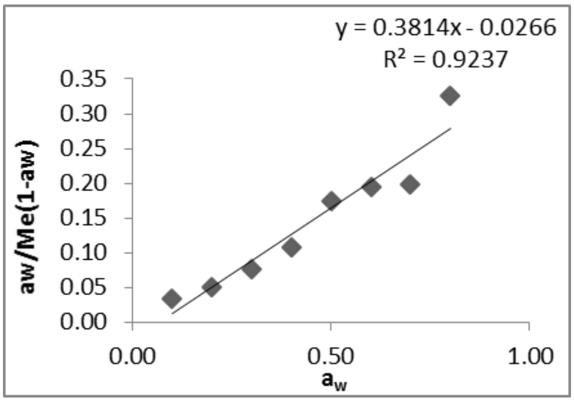

Fig 5: BET model plot of untreated breadfruit flour

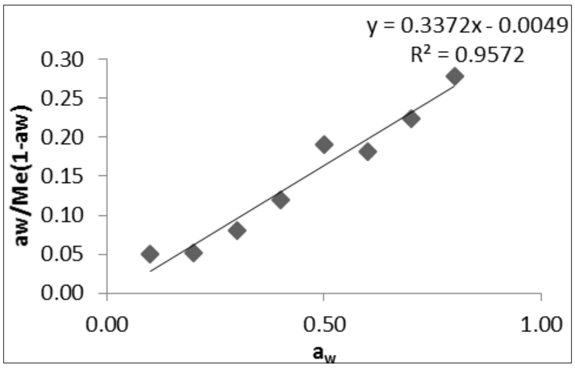

Fig 6: BET model plot of pH-3 buffer treated breadfruit flour

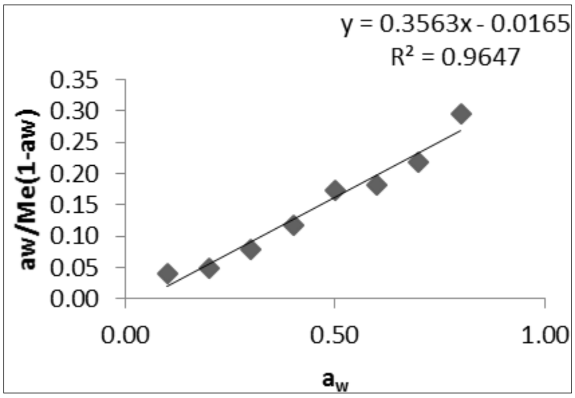

Fig 7:.BET model plot of microwave radiation treated breadfruit flour

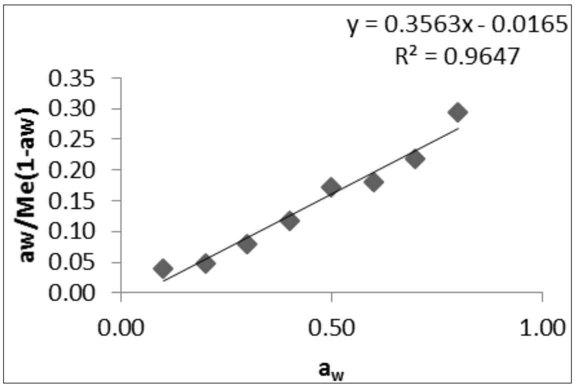

Fig 8: BET model plot of EDTA treated breadfruit flour

Quality of fitness of GAB and BET model equations

The quality of fitness of the model equations which depict the ability of the equations to describe the moisture sorption isotherm of breadfruit flour was evaluated [i.e. comparison of experimental equilibrium moisture values (M_{exp}) with predicted equilibrium moisture values (M_{pre})] by calculating the Mean Relative Deviation Modulus (%E), Standard Error of Estimate (SEE) and Coefficient of Correlation (R) using equations 3.0, 3.1 and 3.2 respectively.

Mean relative percentage deviation

$$(\%E) = \frac{100}{N} \frac{\sum / Mexp - Mpre /}{Mexp} \quad \ldots\ldots (3.0)$$

$$\text{Standard error of estimate (SSE)} = \sqrt{\frac{\sum (Mexp - Mpre)^2}{df}} \quad \ldots (3.1)$$

$$\text{Coefficient of correlation} = \sqrt{1 - \frac{\sum (Mexp - Mpre)^2}{\sum (Mean\ Mexp - Mexp)^2}} \quad ..(3.2)$$

Statistics

The experiments were carried out in duplicates; values reported were averages of two determinations.

Results and Discussion

Moisture sorption Isotherm

Table 1 shows the equilibrium moisture content and Figure 9 shows the moisture sorption isotherms of untreated, pH-3 buffer treated, microwave radiation treated and EDTA treated breadfruit flours. These results show the moisture sorption isotherm of breadfruit flour and how the pretreatments affected the moisture sorption. Isotherms of breadfruit flours have sigmoid shape indicating that equilibrium moisture content increased as the water activity increased. This was due to ability of the flour components (starch and fibre) to absorb moisture through hydrogen bonding with water molecules (BeMiller and Whistler, 1996; Kuye and Sanni, 2002) [13, 17]. This occurred mostly in the amorphous part of starch, the crystalline part is usually resistant to penetration of solvent. However the increase in equilibrium moisture content was gradual within the range 0.0 - 0.5 water activity but increased sharply when the water activity was beyond this range. This is similar to the pattern reported in previous reports on cocoyam flour (Owuamanam *et al*., 2010) [28] and *gari* (Oluwamukomi, 2009) [25]. This observation might be attributed to the fact that at elevated water activity range the sorption of water was due to biopolymers, sugars and other low molecular weight components of food. Owuamanam *et al*. (2010) [28] attributed high moisture uptake of cocoyam flour at higher water activity values to the high sugar content of the flour. At higher water activity low molecular components, apart from biopolymers, also contribute to sorption of water. Additionally, at high water activity, the insipid starch granules swelling caused by the adsorbed water reduced the degree of crystallinity and subsequently increased availability of more water binding sites (Aguirre-Cruz *et al*., 2010; Al-Muhtaseb *et al*., 2004) [3, 8]. The pattern of increase in equilibrium moisture content suggests that storage of breadfruit flour should be done at lower relative humidity. The isotherms of the breadfruit flours are type II according to Brunauer *et al*. (1938) [14] classification and these are typical of sorption isotherms of most food samples especially starchy products (Al-Muhtaseb *et al*., 2002; Neagu *et al*., 2009) [7, 21].

Table 1: Equilibrium moisture content (g/100g db) of breadfruit flours

Equilibrium Moisture Content (g/100g db) for Breadfruit Flours				
Water Activity	**Untreated Breadfruit Flour**	**pH-3 Buffer Treated Breadfruit Flour**	**Microwave Radiation Treated Breadfruit Flour**	**EDTATreated Breadfruit Flour**
0.10	3.39	2.21	5.38	2.77
0.20	4.92	4.89	5.31	5.16
0.30	5.61	5.29	5.72	5.45
0.40	6.19	5.60	6.10	5.71
0.50	5.71	5.26	5.83	5.80
0.60	7.73	8.26	7.77	8.27
0.70	11.77	10.43	8.74	10.69
0.80	12.30	14.37	13.59	13.59

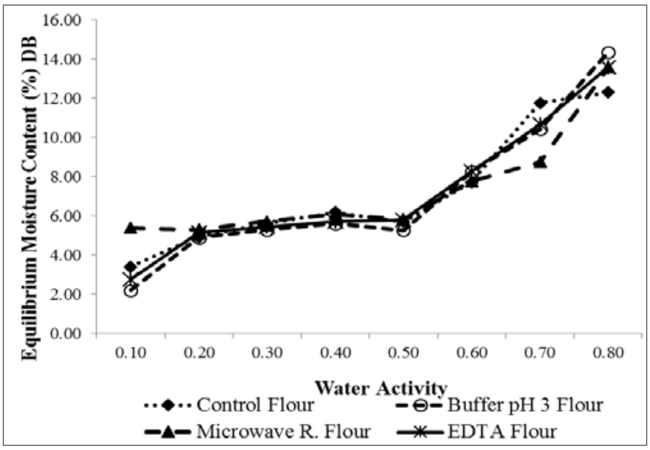

Fig 9: Moisture sorption isotherm of breadfruit flours

Monolayer moisture content and model constants (C and K)

The Guggernheim-Anderson-de Boer (GAB) Model Parabolic Plots and Brunauer-Emmett-Teller (BET) Model Plots were used to find the model parameters of breadfruit flours. Table 2 presents the values of GAB and BET constants i.e. monolayer moisture content (Mo) and the model constants (C and K) of untreated and treated breadfruit flours. GAB monolayer moisture content of untreated breadfruit flour, breadfruit flours treated with pH-3 buffer, microwave radiation and EDTA were 3.79 g/100g, 3.67 g/100g, 3.30 g/100g and 3.80 g/100g (db) respectively while the BET monolayer moisture contents were 2.82 g/100g, 3.01 g/100g, 2.69 g/100g and 2.94 g/100g respectively. The difference in monolayer values indicates that pretreatment affected the mechanism of water adsorption; this may be due to impact of the pretreatment on pH of the flour, crystallinity of starch granules and other constituents of the flour leading to provision of more sorption sites as observed in pH-3 buffer and EDTA treated flours, and less sorption sites as observed in microwave treated flour. Aguirre-Cruz *et al*. (2010) [3] reported that reduction in the sorption sites leads to reduction in the monolayer moisture content. Higher monolayer values of pH-3 buffer and EDTA treated samples above that of microwave radiation treated samples may be as a result of provision of more hydrogen sites that can readily bind with the hydroxyl group of water leading to higher monolayer values; the pH values of the two samples (5.70 and 5.86 for pH-3 buffer and EDTA treated samples respectively) were lower than that of microwave treated sample (5.90). Low monolayer value for microwave treated sample may be attributed to retrogradation which is associated mainly with amylose fraction of starch. Microwave radiation may have enhanced the re-association of amylose in stored breadfruit flour. Starch can retrograde in solid state and at low moisture content (Obiegbuna *et al*., 2014) [22], during which the linear chains of amylose align themselves to form crystalloid region with the release of part of its bound water. These regions become hydrophobic as bound water is replaced by intermolecular bonds of carbon–carbon hydroxyl group (Obiegbuna *et al*., 2014) [22] and the retrograded starch molecules becomes tightly packed with the reduction of sorption sites since no water can be held within the crystals. Damodaran *et al*. (2008) [15] had reported that sample pretreatment is one of the factors that can affect moisture sorption isotherm of food materials. Al-Muhtaseb *et al*. (2002) [7] listed composition of foods, pretreatment and experimental method used to determine sorption isotherm as some factors that affect sorption properties of foods. GAB monolayer moisture contents of all the flours were higher than monolayer moisture of BET, this is consistent with previous reports (Abramovic and Klofutar, 2002; Timmermann, 2003) [1, 29]. The range of monolayer values of breadfruit flours obtained in this research generally corresponds to about 0.2 water activity, this value was lower than the maximum water activity (0.35 – 5.0) that can be permitted by dehydrated materials without loss of desirable properties during storage (Damodaran *et al*., 2008; Labuza and Contreras-Medellin, 1981) [15, 18]. Monolayer moisture contents of breadfruit flours obtained was lower than 3.87g/100g – 5.88g/100g (db) reported for banana flour (Aguirre-Cruz *et. al*., 2010) [3], 4.90g/100g – 5.80g/100g (db) reported for cassava tapioca (Kuye and Sanni, 2002) [17], 5.00g/100g – 8.00g/100g (db) reported for cassava gari (Oluwamukomi, 2009) [25], and 10.00 g/100g (db) the maximum value reported for the shelf stability of food materials (Kaymak-Ertekin and Sultanoglu, 2001) [16].

Monolayer moisture contents of foods conform to stability of dehydrated food (Al-Muhtaseb *et al*., 2002) [7]. Monolayer value, which is of considerable practical importance, indicates the water content that ensures greatest stability of a dehydrated product (Damodaran *et al*., 2008) [15]. Monolayer moisture content can also be the lowest quantity of water tightly bound to water absorption site that guarantees the shelf stability of food materials during storage; low monolayer value ensures better storage stability of the material (Osundahunsi *et al*., 2014) [26]. Microwave radiation treated flour had the minimum monolayer moisture contents for the two isotherm model equations which suggest that the sample had fewer sorption sites when compared with other samples. This indicates that the sample would have higher storage stability than the other flour samples. However since most dried food materials exhibit their best stability at moisture contents close to the monolayer value (Al-Muhtaseb *et al*., 2002) [7], samples with relatively high monolayer values may be preferred because of relative ease of drying the sample to moisture content comparable to such high monolayer value without adverse effect of heat on the sample. Attempt to dry food material to very low moisture content can cause colour change, oxidation, rancidity, excessive gelatinization and denaturation, inability to reconstitute easily as a result of the effect of heat.

The results shows that untreated breadfruit flour had the highest GAB constant value of C and lowest value of K. C and K are model constants; K is the GAB constant that is associated with the properties of molecules at the multilayer (Andrade *et al*., 2011) [9]. The K values for the samples were generally less than 1, this conform with GAB model's assumption that the property of sorbed water molecules in second layer is similar to the one in first monolayer, but different from property of molecules in the liquid state i.e. the properties of multilayer moisture is between that of monolayer moisture and bulk liquid (Oluwamukomi, 2009)[25]. Similar observations were reported for banana flour (Aguirre-Cruz *et al*., 2010) [3] and cassava tapioca (Kuye and Sanni, 2002) [17]. The pH-3 buffer treated sample had the lowest BET constant C; C is the model energy constant which indicate the difference between the heat of sorption of molecules at the first layer and other layers (Andrade *et al*., 2011) [9].

Table 2: Monolayer moisture value (mo) and model constants (c and k) values of breadfruit flours

Models	Parameters	Breadfruit Flour	pH-3 Buffer Treated Breadfruit Flour	Microwave Radiation Treated Breadfruit Flour	EDTA Treated Breadfruit Flour
GAB	Mo (g/100g db)	3.79	3.67	3.30	3.80
	C	97.61	24.48	-22.08	58.12
	K	0.89	0.93	0.91	0.91
BET	Mo	2.82	3.01	2.69	2.94
	C	-13.34	-67.82	-10.16	-20.59

Fittings of GAB and BET sorption models to the experimental sorption data

Table 3.0 presents the data for the goodness of fit of the two sorption model equations. Mean relative deviation modulus (%E), standard error of estimate (SEE) and coefficient of correlation (R) were used to assess the goodness of fit of the equations when the experimental equilibrium moisture contents were compared with the GAB and BET predicted equilibrium moisture contents.

Mean relative deviation modulus (%E) values of the breadfruit flours, which is an index of deviation of predicted values from experimental values, were in the range 9.07% - 12.49% for GAB model and 14.09% - 20.66% for BET model; generally the lower the %E the better is the fitness of isotherm model data with those of experimental values. Mean relative deviation modulus (%E) values of GAB model, which were generally lower than that of BET model, were comparable to maximum value of 10% assumed as an indication of good fit of isotherm (Lopes-Filho *et al*., 2002) [19]. This shows that GAB model could be used as appropriate model equation to predict the moisture sorption properties of breadfruit flour better than the BET model. Additionally, the values for microwave radiation and EDTA treated flours (9.07% and 9.72% respectively) were lower than that of other samples, this indicates that there was better fitness for the microwave radiation and EDTA treated flours than for the other samples. Standard error of estimate (SEE) measures the level of error in the estimation of equilibrium values from model equation and could be used to analyze the goodness of isotherm equation. SEE values of GAB model for breadfruit flours with a range 0.75 - 0.92 was consistently lower than that of BET model (0.90 - 1.56), the lower the SEE the better is the ability of model to predict the sorption isotherm of food material. This also confirmed the superiority of GAB model equation over BET model equation for breadfruit flour.

The coefficient of correlation (R) between the experimental equilibrium moisture content and predicted equilibrium moisture content followed the same trend as that of %E and SEE, and it shows that experimental values were positively correlated with the predicted values. Generally, the higher the value of correlation coefficient (R) the better is the correlation between the experimental data and the predicted data. GAB R values for untreated flour, pH-3 buffer, microwave radiation and EDTA treated breadfruit flours (0.96, 0.98, 0.99 and 0.98 respectively) were consistently higher than that of BET except for the R value of pH-3 buffer treated sample which was 1.00; this indicates the superiority of GAB equation over BET equation in predicting the sorption isotherm of breadfruit flour. Generally the results showed a better fitness and correlation between the equilibrium moisture values obtained from the experiment and the one predicted by GAB model than that predicted by BET model. GAB model equation was reported to be a choice model equation due to its recommendation by the European Project Group COST 90 on the Physical Properties of Foods as the basic model that could be used to examine the sorption isotherm of food products (Ajisegiri *et al*., 2007; Oluwamukomi, 2009) [6, 25]. It is used for wide range of water activity and for food materials that have high carbohydrate content. This may explain its performance in this study as a reliable model equation to predict the moisture sorption of breadfruit flour (a high carbohydrate food material) over the water activity range used in this study. The low goodness of fit of BET equation in this study when compared with GAB equation may be as a result of limitation of BET model in predicting moisture sorption of food materials in water activity range above 0.4. However, its common use in evaluation of monolayer values is attributed to simplicity of its application and its approval by the International Union of Pure and Applied Chemistry (IUPAC) (Timmermann, 2003) [29]. Water molecules are associated with food components in variety of ways in different relative humidity regions; as a result of this a single sorption isotherm model cannot adequately described the sorption characteristics of food materials over the entire range of relative humidity.(Al-Muhtaseb *et al*., 2002) [7].

Conclusion

The equilibrium moisture contents of treated and untreated breadfruit flours increased with increase in water activity values. Sorption isotherms of the flours at 30^{o}C were sigmoid in shape. Monolayer moisture contents of treated and untreated breadfruit flours were below the 10% maximum recommended for all food materials. Pretreatment affected the moisture sorption characteristics of breadfruit flour and microwave radiation treated flour had the lowest monolayer moisture content. The mean relative deviation modulus (%E), standard error of estimate (SEE) and coefficient of correlation (R) utilized to evaluate the goodness of fit of the two model equations (GAB and BET) show that GAB model was more appropriate for the description of moisture sorption of breadfruit flour. This moisture isotherm study could be used to predict the property of the flour during storage under different relative humidity at the temperature studied.

Acknowledgement

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Conflicts of interest

The authors declare no conflict of interest

Table 3: Experimental value and predicted value of equilibrium moisture contents (g/100g db) of breadfruit flours and parameter values of goodness of fit of the two model equations

aW	Breadfruit flour			Ph-3 buffer treated breadfruit flour			Microwave radiation treated breadfruit flour			Edta treated breadfruit flour		
	Experimental	Gab predicted	Bet predicted	Experimental	Gab predicted	Bet predicted	Experimental	Gab predicted	Bet predicted	Experimental	Gab predicted	Bet predicted
0.10	3.39	4.02	3.13	2.21	2.89	3.34	5.38	6.62	2.99	2.77	3.56	3.27
0.20	4.92	4.54	3.52	4.89	3.82	3.76	5.31	5.07	3.36	5.16	4.31	3.68
0.30	5.61	5.12	4.03	5.29	4.60	4.30	5.72	5.17	3.84	5.45	4.99	4.20
0.40	6.19	5.84	4.70	5.60	5.46	5.02	6.10	5.65	4.48	5.71	5.78	4.90
0.50	5.71	6.78	5.64	5.26	6.54	6.02	5.83	6.43	5.38	5.80	6.80	5.89
0.60	7.73	8.07	7.05	8.26	8.01	7.52	7.77	7.60	6.72	8.27	8.20	7.36
0.70	11.77	9.97	9.39	10.43	10.23	10.03	8.74	9.41	8.96	10.69	10.27	9.81
0.80	12.30	13.01	14.09	14.37	14.01	15.05	13.59	12.49	13.44	13.59	13.69	14.71
SEE		0.92	1.52		0.75	0.90		0.77	1.56		0.63	1.04
%E		10.62	16.68		12.49	16.91		9.07	20.66		9.72	14.09
R		0.96	0.88		0.98	1.00		0.99	0.83		0.98	0.95

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