Full Length Research Paper

Moisture adsorption of sprouted bambara groundnut flour (*Vigna subterranean*)

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Abstract

This study investigated the moisture adsorption characteristics of sprouted Bambara groundnut (*Vigna subterranean*). The adsorption isotherm for sprouted Bambara groundnut was determined and studied at room temperature (27±2 °C) using the static gravimetric method. Samples were equilibrated in desiccators containing tetraoxosulphate (VI) acid solution of known relative humidity varied from 20%, 30%, 40% and 50%. The moisture content was then calculated using the data of initial moisture content and the amount of moisture gained or lost at equilibrium. The desiccators were made into each relative humidity and were studied at room temperature (27±2 °C). The plot of equilibrium moisture content against water activity at 20%, 30%, 40% and 50% for adsorption process gave a sigmoidal shaped isotherm curve. The equilibrium moisture content value increased with water activity. The Henderson and Oswin models gave the best fit and could be used to present the moisture adsorption isotherm of sprouted bambara groundnut flour for water activity content range of 0.2 to 0.5.

Keywords: Sprouted bambara groundnut, moisture adsorption, equilibrium moisture content, relative humidity

INTRODUCTON

Moisture sorption isotherms are useful thermodynamic tools for determining the interaction of water and food substances. They also provide information for assessing food processing operations, such as drying, mixing, packing and storage. Such data can be used for selecting appropriate storage conditions and packing systems that optimize or maximize the retention of aroma, colour, texture, nutrients and biological stability (Labuza *et al*, 1985 and Rizvi, 1995). Moisture sorption isotherms show the dependence of the water content on the water activity (aw) of a food at a definite temperature and pressure.

The knowledge of water activity is a better indicator in understanding the storage stability of food materials than water content, but the knowledge of moisture alone is not sufficient to predict the stability of foods. The quality of most food materials preserved by drying depends largely on their physical, chemical and microbiological stability. At constant temperature, the moisture content of the food changes until it reaches an equilibrium with the water vapour of the surrounding air. The movement of water vapour from the food material to the surrounding air depends on the food material and the condition of the surrounding air (temperature and humidity).

Food legumes have a major role to play in the fight against malnutrition. It is therefore necessary that their levels of consumption, which are too low in a number of developing countries, should be increased. Legumes serve as a source of protein to a large proportion of the population in the poor countries of the world by being the least expensive and easily stored and transported non processed protein source for rural and urban dwellers (Rachie and Silvester, 1977). The high carbohydrate

(65%) and relatively high protein (18%) content of Bambara groundnut make it a complete food.

Sprouting seeds of most cereals and legumes have shown improvements in nutrients in human diet and compare well with their fresh counterparts if not better (Kakade and Evans, 1966; Kylen and McCready, 1975). Studies have shown that although legumes are known for their high protein content, their utility is limited because of the low protein digestibility. A combination of sprouting and cooking resulted in an excellent digestibility coefficient (El-Hag *et al.*, 1978; Ologhobo and Fetuga, 1986). Germination resulted in greater retention of all minerals and B-complex vitamins compared to cooking treatment in chickpeas (El-Adawy, 2002). Germination increased amount of thiamin, riboflavin, niacin and ascorbic acid in both soybean and mung bean. Mineral values in sprouted beans increased with the germination except with iron. Iron values decreased in sprouted seeds but its availability increased due to an increase in phytase activity during seed germination 24h (Bates *et al.*, 1977; Walker and Kochhar, 1982). As germination takes place, the anti-nutritional factors are greatly decreased to insignificant levels or to nothing (Siddhuraju and Becker, 2001; El-Adawy, 2002; Ugwu and Oranye, 2006).

Lots of research work has been done on the effect of processing methods such as sprouting on bambara groundnut. However, little research has been done on the adsorption characteristics of sprouted bambara groundnut, hence this research work investigated the moisture adsorption characteristics of sprouted bambara groundnut flour.

MATERIALS AND METHODS

Preparation of sprouted bambara groundnut flour

The bambara groundnut purchased from Kuto market in Abeokuta, Ogun State was sorted, cleaned and spread in a malting chamber for 7 days to allow germination during which the nuts were sprinkle with water and turned at intervals. The germinated bambara nuts were dried in an electric oven at temperature of 45 °C for 24 hours. After the drying, the sprouted bambara groundnuts were dry milled using grinding machine and sieved to remove shaft. The resulted flour was kept in a polythene bag for further use.

Microclimate conditioning

The required micro climate was prepared from various concentrations of sulphuric acid in creating relative humidity ranging from 20% - 50% at room temperature, namely: 20% Relative humidity = 20% distilled water + 80% H_2SO_4, 30% Relative humidity = 30% distilled water + 70% H_2SO_4, 40% Relative humidity = 40% distilled

water + 60% H_2SO_4, 50% Relative humidity = 50% distilled water + 50% H_2SO_4 (Alakali and Satimehin, 2009).

Determination of adsorption isotherm

Static gravimetric method was used. 5.0g of sprouted Bambara groundnut flour were weighed in triplicate into moisture pans and placed on wire gauze in the micro desiccator (Ajibola, 1986). The micro desiccators containing the samples were kept in the large desiccator at room temperature with relative humidity of 20% until constant weight was attained. The samples were weighed at 1 hour intervals until three successive readings were each less than 0.5 % of the previous one. The moisture content was calculated by subtracting the initial weight of the sample from the final weight of the sample after completion of time using the data of initial moisture content and the amount of moisture gained or lost at equilibrium. The procedure was repeated for the replicate samples at 30%, 40% and 50% relative humidity and the moisture content was also calculated in the same manner. The moisture content of the equilibrated samples on dry basis was then plotted against the relative humidity so as attain isotherm curve.

Determination of equilibrium moisture content

Equilibrium moisture content was determined by calculating the original moisture content and the known change in weight on dry basis (Oyelade *et al.*, 2008). The relation below is used in calculating the equilibrium moisture content (EMC) of the samples.

EMC = (Adsorbed moisture / Weight of sample) X 100

Determination of water activity

The water activity a_w of the sample was determined from the relative humidity of the air surrounding the sample when the air and the sample are at equilibrium which is equilibrium relative humidity. The equilibrium relative humidity value was divided by 100 to get the water (a_w) value.

Mathematical Model

The experimental equilibrium moisture content (EMC) data were processed using
Microsoft Excel (2010) software and analyzed using the Henderson, Oswin and Smith models. The parameters of the models were calculated by direct non-linear

Table 1. The mean values of adsorption isotherm of sprouted Bambara groundnut flour.
Time Humidity (%)

(Hour)	20	30	40	50
0	5.00±0.01	5.00±0.01	5.00±0.04	5.00±0.01
2	5.26±0.02	5.24±0.01	5.28±0.01	5.31±0.01
4	5.26±0.02	5.24±0.01	5.28±0.01	4.31±0.02
6	5.29±0.01	5.31±0.01	5.31±0.01	5.36±0.01
8	5.32±0.01	5.35±0.01	5.36±0.01	5.38±0.01
21	5.31±0.01	5.35±0.01	5.36±0.01	5.38±0.01
23	5.32±0.01	5.35±0.01	5.36±0.01	5.38±0.01

Table 2. Calculated moisture content and equilibrium moisture content values of sprouted bambara groundnut flour.

Relative humidity (%)				Time	(Hour)			Absorbed moisture	Equilibrium moisture content	Water activity
	0	2	4	6	8	21	23			
20	5.00	5.14	5.26	5.29	5.32	5.31	5.32	0.32	6.40	0.2
30	5.00	5.10	5.24	5.31	5.35	5.35	5.35	0.35	7.00	0.3
40	5.00	5.17	5.28	5.31	5.36	5.36	5.36	0.36	7.20	0.4
50	5.00	5.19	5.31	5.36	5.38	5.37	5.38	0.38	7.60	0.5

regression analysis using DATAFIT package.

Henderson parameters

This is a commonly used model and it can be expressed as it is described in equation 1.

$$M_w = \left(-\frac{\ln(1 - a_w)}{c} \right)^{1/n} \quad \text{----------------- (1)}$$

where C and n are constants.

According to this model, a plot of ln [–ln(1 –aw)] versus ln Mw should give a straight line.

Oswin parameters

It is an empirical model that consists in a series expansion for sigmoid shaped curves and it was developed by Oswin, 1946. It is described in equation 2:

$$\text{-------------------------- (2)}$$
$$M_w = C \left(\frac{a_w}{1 - a_w} \right)^n$$

where C and n are constants.
The Oswin equation was used to relate the moisture content of fat free dry milk and freeze dried tea up to a water activity of 0.5 (Oswin, 1946), as well as for various foods.

Smith parameters

In 1947, Smith developed an empirical model to describe the final curved portion of water sorption isotherm of high molecular weight biopolymers.
This model can be written as equation 3:

$$M_w = C_1 + C_2 \ln(1 - a_w) \quad \text{-------------------- (3)}$$

where C_1 is the quantity of water in the first sorbed fraction, and C2 is the quantity of water in the multilayer moisture fraction.
This equation could be used in the water activity range from 0.5 to 0.95 in the case of wheat desorption and for various products.

RESULTS AND DISCUSSION

Moisture sorption characteristics of sprouted bambara groundnut flour

The mean values and standard deviations of sorption isotherms of sprouted Bambara groundnut flour are presented in Table 1. The calculated moisture content and Equilibrium Moisture Content (EMC) are presented in Table 2 at different times and relative humidity.
Sorption isotherms of sprouted Bambara groundnut flour at room temperature in the a_w range of 0.2 to 0.5 are
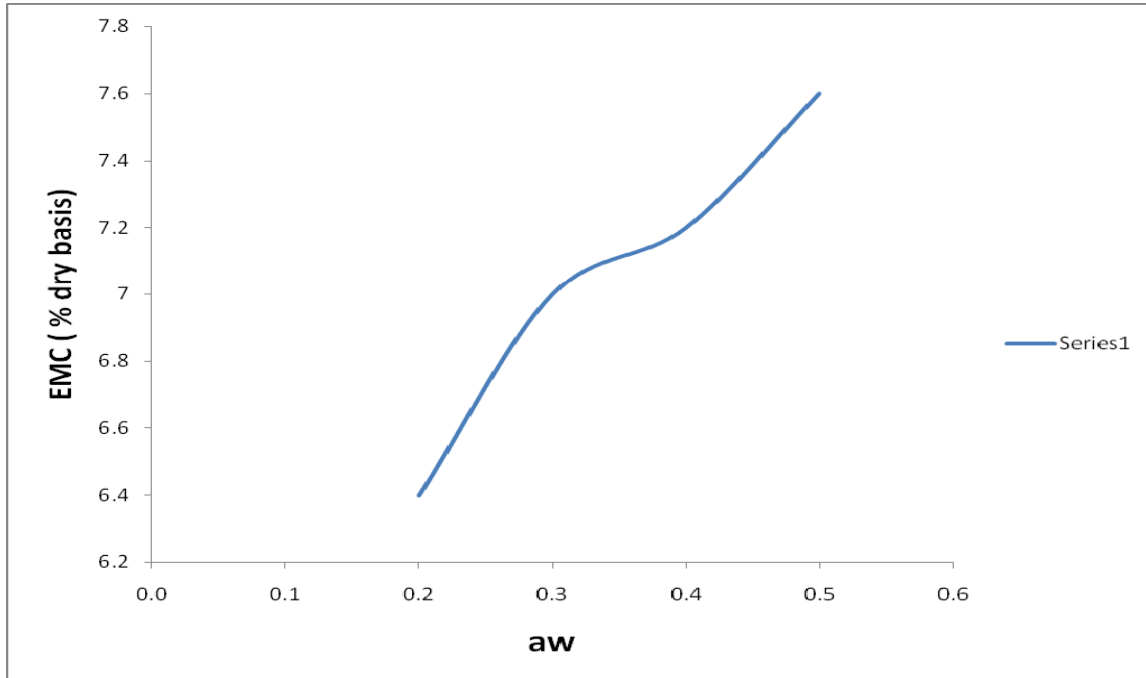
Figure 1. Equilibrium Moisture Content versus Water activity

Table 3. Parameter values for all models in adsorption of sprouted Bambara groundnut flour

Models	Values
Henderson	
A	1.28 X 10 -6
B	6.4979
R^2	0.9736
SE	0.099
Oswin	
A	7.6065
B	0.1179
R^2	0.9735
SE	0.099
Smith	
c1	5.9799
c2	2.3996
R^2	0.9438
SE	0.1452

shown in Figure 1, which follow the characteristic sigmoidal sorption isotherm (type II isotherm) according to the classification of Brunauer *et al.* (1940) in which the curves are concave upwards; and it takes into account the existence of multilayers at the internal surface of a material. This is the type of isotherm most commonly found in food products. The isotherm was similar to that of yam flour as reported by Oyelade *et al.* (2008), which was sigmoidal in shape. It was observed that the EMC increased sharply as the water activities increased.

These findings were in agreement with those of Budi and Jenshinn (2010) for the adsorption characteristics of Taro flour.

Curve fitting of sorption isotherms of sprouted bambara groundnut flour

The estimated parameters of the Henderson, Oswin and Smith models are presented in Table 3. The A value of

Oswin model (7.6065) was greater than that of Henderson model (1.28 X 10 -6). Whereas, the B value of Henderson was greater than (6.4979) that of Oswin model (0.1179).

The three models have low SE values (less than 0.5) and higher R^2 (higher than 0.9). Thus, it can be concluded that the three were well fitted for adsorption isotherms of sprouted Bambara groundnut flour. That was in close agreement with the finding of Budi and Jenshinn, (2010) for the adsorption characteristics of Taro flour. However, SE value (0.1452) of the Smith model was higher than that of Henderson and Oswin models with the same value, (0.099).

Also, Henderson and Oswin models have the same value of R^2 (0.97) greater than Smith value (0.94). Therefore, the Henderson and Oswin models could be considered as the most appropriate model for the moisture adsorption isotherms of sprouted Bambara groundnut flour.

CONCLUSION

Moisture sorption isotherms of sprouted bambara groundnut flour exhibited sigmoidal shape described as type II, typical of foodstuff. The EMC values increased with increased water activity. The Henderson and Oswin models described the sorption data well over the of water activities studied in this investigation as the Henderson and Oswin model could be satisfactorily used to predict the moisture sorption isotherms of sprouted Bambara groundnut flour for water activity between 0.2 - 0.5.

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