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Determination of Functional Properties and Moisture Sorption Isotherm of Dried Bean Flour

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ABSTRACT

Beans flour was produced and characterized in terms of functional properties and the moisture sorption isotherm. The results obtained from the functional properties indicate that Water absorption capacity is 2.58±0.60%, Oil absorption capacity is 3.05±0.20%, bulk density is 0.62±0.63kg/m^3, swelling capacity is 431.37±10.89% and Gelatinization temperature is found to be 64.30±0.90^{O}C. Sorption data were analysed according to the equation proposed by Oswin and Halsey and a linear graph was plotted which is use to estimate the constant C and n of each models. These constants are used to estimate the various water activity and the calculated values of equilibrium moisture content. The calculated values were then compared with the experimental value and were found to compare well. The calculated value obtained was used against aw to plot an isotherm curve. The isotherm curve obtained fit in to a sigmoid and floury huggins shape isotherm of type II and III. Both Oswin and Halsey equation gave a fair coefficient of correlation (0.6571 and 0.6762) respectively. Therefore, both equations are considered fit.

Keywords: Beans Flour, Sorption Isotherm, Functional Properties

1.0 INTRODUCTION

Cowpea is one of the most important grain legumes in Nigeria and other West Africa. It can be consumed in various forms, mainly processed and eaten as *moi-moi*, *akara*, *danwake* etc. or cooked together with a cereal grain, usually rice, or with a root or tuber such as yam, cocoyam, potatoes etc. These cowpeas are the main source of protein for low income Nigerians (Mamiro *et al.,* 2011; Haruna and Usman 2013). Traditional food preparation is laborious, so time-consuming that urban residents look at indigenous food preparation with disdain. Olapade *et al*., (2005) and Owuamanam *et al.*,(2013) stressed the need for the use of cowpea flour for preparation of cowpea based products such as *moimoi*, *akara*, in order to avoid such unit operations as soaking, dehulling, wet milling. Cowpea seeds contain 20-25% protein, 1.5-4% crude fiber, 1-2% fat, 3-4% ash and 55-68% carbohydrate in addition to vitamins and beneficial phytochemicals (Lasekan et *al.,* 1987; Frank–Peterside *et al.,* 2002). Processing methods such as dehulling, soaking, cooking, germination, fermentation etc. help reduce or eliminate anti-nutrients which according to Singh (1988) and Bressani (1993) include protease inhibitors, goitrogenic factors, flatulence factors, hemagglutinins, phytates etc. which individually or collectively reduce protein or carbohydrate digestibility, mineral and vitamin bioavailability (Mosha and Svanberg 1990; Ahmed *et al.,* 2006). Steeping and germination activates endogenous and exogenous enzymes that modify the seed polymeric units into simpler highly absorbable forms, decrease anti-nutrients and liberate chelated minerals (Mega 1982; Chavan *et al.,* 1988). However, dehulling the cowpea seeds prior to *moi-moi* or *akara* preparation deprives the consumers the needed dietary fiber that ensures healthy digestive system, reduce the risk of chronic diseases such as diabetes, obesity, cardio-vascular diseases through lowering bad cholesterol and postprandial glucose surge (Walker 1982; Ahmed *et al.,* 2006). Cereal grains and legumes mutually complement each other when consumed together in a beneficial ratio (28:72, legume: cereal) therein they provide equal amounts of highly needed quality protein (Bressani 1993). The common traditional practice of consuming cowpea-based products alongside with cereal foods (Ogi, kunu zaki, bread etc.) in Nigeria is long and how it started like many other food habits or practices is uncertain. Supplementation of cowpea with maize will ensure better amino-acid profile; lysine deficient maize protein complements the sulphur amino acids lacking in cowpea thereby enhancing the nutritive value of a meal e.g *moi-moi*. In all these applications, the functional properties and sorption behavior of the flour are important in product formulation and specification of process parameters. Functional properties are fundamental physico-chemical properties that is use to reflect the complex interaction between the composition, structure and molecular conformation of food components together with the nature of environment in which it is associated and measured (Okezie and Bello, 1988). Functional characteristics are required to evaluate and possibly help to predict how new proteins, fat, fibre and carbohydrates may behave in specific systems as well as demonstrate whether or not such protein can be used to stimulate or replace conventional protein (Okechukwu and Rao, 1997). The food property is characterized by the structure, quality, nutritional value and acceptability of a food product. A functional property of food is determined by physical, chemical and organoleptic properties of the food. In this study, the Functional properties analyzed include swelling capacity, Oil absorption capacity, water absorption capacity, Bulk density and Gelatinization temperature. Packaged food powders absorb water during storage to cause a change in chemical composition and functional properties (Akubor *et al.*, 2017). Knowledge of the moisture sorption behavior of sugar containing foods like flour is very important in selecting packaging materials as well as predicting the stability and moisture changes during storage (Al-muhtaseb *et al.*, 2004). Investigating structural features such as specific surface area, pore volume, pore size distribution and crystalline of a food product requires the knowledge of Moisture sorption isotherm (Ariahu *et al.*, 2006). Such data are useful in selecting appropriate storage conditions and packaging systems that optimize or minimize retention of aroma, color, texture, nutrients including biological stability (Eke *et al*., 2011).

Preparation of beans based food from the scratch is labour intensive and stressful. The flour produce will help create convenience where only water will be required for reconstitution. It will increase the utilization of cowpea, increase the product shelf life and enhance food availability and safety by just picking the flour at retail centres. It will also increase consumption of cowpea based products like *moi-moi* and *akara*. This work is therefore designed to characterize dried beans flour in terms of its functional properties and moisture sorption isotherm which are important storage and in the reconstitution ability of the dry flour.

2.0 MATERIALS AND METHODS

Preparation of Cowpea Flour: Black eyed Cowpea grains were use in this study. It was purchased from Kure ultramodern market at Minna, Niger state and conveyed to the laboratory in a clean polythene bag. The cowpea flour was prepared using the method described by Okezie and Bello (1988). The beans grain was sorted cleaned to remove extraneous materials, dirt and infected seeds. The seeds were then milled into flour after drying preceded by dehulling which was done by soaking in water for 30 minute. This helps to loosen the hulls easily from the seed. The flour obtained was sieved into fine flour and stored in an air tight container for later use.

2.1 Determination of Functional Properties

Water Absorption Capacity: The water absorption capacity was determined by the method of AOAC (2010). Two grams of the sample powder was weigh into centrifuge tube and 20ml of distilled water was added, the tube was shaken and allowed to stand at room temperature (25^{0}C) for 30mins and then centrifuged for 30min at 200rpm. The excess water was decanted by inverting the tubes and the weight of the water bound was determined by difference.

$$\text{Water absorption capacity} = \frac{W_2 - W_1}{W_0}$$

Where;

W_0= weight of sample W_1= weight of tube

W_2= weight of tube and sample.

2.2 Oil Absorption Capacity

The oil absorption capacity was determined by the method of AOAC (2010). Two grams of the sample powder was weigh into a centrifuge tube and 20ml of oil was added and the tube was shaken and allowed to stand at room temperature (25^{o}C) for 30mins. It was then centrifuge for 30min at 200rpm and the excess oil was decanted by inverting the tubes and the weight of the oil bound was determined by difference.

$$\text{Oil absorption capacity} = \frac{W_2 - W_1}{W_0}$$

Where;
W_0= weight of sample W_1= weight of tube
W_2= weight of tube and sample.

2.3 Bulk Density

The bulk density was determined using the method of AOAC (2010). Twenty grams of sample was weighed into 100 ml of a graduated cylinder. The cylinder was then tapped ten times against the palm. After that, the cylinder was placed on the table and the final volume read. Bulk density (g/ml) was calculated as follows:

$$\text{Bulk density} = \frac{w_1}{w_2}$$

Where;
W_1 = Mass of material W_2 = Volume of material after tapping

2.4 Swelling Capacity

The swelling capacity was determined by the method of AOAC (2010). The tube containing sample after water has been decanted during water absorption capacity was heated in an oven for 24 hours. The dish was then removed from the oven, cooled in a desiccator and weighed.

$$\text{Swelling capacity} = \frac{W_1 - W_2}{W_0} X\ 100$$

Where;
W_0= weight of tube after oven heat W_1= weight of tube W_2= weight of sample

Gelatinization Temperature: Gelatinization temperature was determined by making slurry of 3g flour sample with 15 ml of water. The sample was heated slowly in a water bath until it forms a solid gel. At complete gel formation, the temperature was measured and taken as gelatinization temperature.

2.5 Determination of Moisture Sorption Isotherm

The moisture sorption of the flour was determined using Halsey and Oswin equations. Halsey equation is a good representation of adsorption data regarding isotherms type I, II, or III. Oswin model consists of series of expansion for the sigmoid shaped curve. The moisture sorption property of the produced cowpea flour was determined using the static gravimetric techniques as describe by Ariahu *et al.*, (2006). Saturated salt solution of sodium chloride was use to obtain different relative humidity environment having water activities between 0.10 - 0.90. The flour sample was placed over the saturated salt solution in the indicator and kept in the temperature control cabinet at 30^{O}C. The samples were been weigh using a digital weighing balance until a constant weight is obtain. Initial moisture content of the flour was determined by oven drying method.

2.6 Data Analysis

Experimental sorption data were compared to the calculated values by correlation to determine the coefficient of determination of fitness of data (R^2).

3.0 RESULTS AND DISCUSSION

3.1 Functional properties

The results of functional properties of the samples were shown in table 1.

Table 1: Functional Properties of Beans Flour

Property	Mean Value
Water Absorption Capacity (%)	2.58±0.60
Oil Absorption Capacity (%)	3.05±0.20
Bulk Density (%)	0.62±0.63
Swelling Capacity (%)	431.37±10.89
Gelatinization Temperature (^{0}C)	64.30±0.90

All values are means of triplicate reading expressed as mean ± SD.

The water absorption capacity (WAC) is 2.58±0.60. This is similar to the range reported by Folawole and Kolawole (2011), Enwere and Ngoddy (1986) for cowpea flours and Adebowale *et al.*, (2005) for mucuna beans flour. Water absorption capacity indicates ability of a product to associate with water under condition where water is limited in other to improve handling characteristics and dough forming capability (Iwe and Onalope, 2001). Oil absorption capacity (OAC) was found to be 3.05.±0.20. This is higher than 0.39 - 0.53 g/g reported for some Nigerian cowpea varities (Chinma et al., 2008). This value indicates that the native proteins have not been altered in cowpea flour. Oil absorption mechanism involves physical entrapment of oil by food component and the affinity of non-polar proteins side chains of lipids (Kinsella 1982, Sathe *et al.*, 1982).WAC and OAC of food protein depend on intrinsic factors like amino acid composition, protein conformation and surface polarity. The ability of the proteins of flour to bind with oil makes it useful in food system where optimum oil adsorption is desired. This make flour to have more functional uses, enhance flavour and mouth feel when use in food preparations. The swelling capacity is 431.37±10.89. The swelling capacity of flours depends on particle size, type of variety and processing method used. The bulk density was observed to be 0.62±0.63 the bulk density depends on particle size and initial moisture content of the flour. It ranges from 0.7g/ml to 0.94g/ml as seen in report by Oyeyinka *et al.*, (2013). High bulk density predicts its stability in various food preparations where as low bulk density reported by Folade and Kolawole (2011). The difference can be attributed to the difference in particle size of cowpea flour (Perez, 1997). From Padmashree *et al.*, (1987) higher bulk density is needed for greater ease of dispersion of flour while low bulk density is an advantage in the formation of complementary foods (Akpata and Akubor, 1999). The bulk density was similar to that reported for other cowpea varieties of pigeon pea 0.68±0.04 (Butt and Batool, 2010). The sample recorded a gelatinization temperature of 64.30ºC. This is slightly below the range proposed by Ajeigbe *et al.*, (2008). Unlike starches, cowpea contains 32% - 53% starch and 24% protein (Okechukwu and Rao 1997) It is reported in literature that flour with high starch content require low temperature for gelatinization to occur.

3.2 Experimental Moisture Sorption Characteristics

Sorption data obtained in the work is shown in Table 2 below. It can be seen that after seven hours of sorption, three consecutive constant weights are obtained indication the attainment of equilibrium moisture content. During this process, the specific regular moisture uptake in gram-water per gram-sample is shown in table 3. Ten grams (10g) of the produced sample was use to analysed successive weight changes with time (1 hour 30 minute).

Table 2: Weight increase in gram per time interval

Relative Humidity	T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_{8-10}	%Me(db)
75	10	10.2	10.2	10.2	10.3	10.3	10.4	10.3	10.4	14.2
77	10	10.2	10.3	10.2	10.2	10.3	10.3	10.3	10.3	13.19
78	10	10.4	10.3	10.3	10.4	10.4	10.4	10.5	10.5	15.38
80	10	10.4	10.4	10.3	10.4	10.4	10.4	10.4	10.4	14.29
81	10	10.3	10.6	10.6	10.6	10.4	10.4	10.6	10.6	16.48
82	10	10.6	10.6	10.6	10.6	10.6	10.6	10.5	10.7	17.58
83	10	10.4	10.4	10.4	10.4	10.5	10.5	10.5	10.5	15.38
85	10	10.5	10.6	10.6	10.6	10.6	10.6	10.6	10.6	16.48
86	10	10.4	10.4	10.4	10.4	10.5	10.5	10.5	10.5	15.38
87	10	10.4	10.2	10.5	10.4	10.5	10.5	10.5	10.5	15.38

All values are means of triplicate readings.
Keys: T = Time, Me (db) = Equilibrium moisture content in dry basis

The experimental data were used to calculate the constants in the linearized equations of both Oswin and Halsey equations, and the constants were presented in table 4. The sorption isotherms exhibit a sigmoid shape; i.e. type II isotherm curve according to the classification made by Bruenaur (Ariahu *et al.*, 2006). Most biological food product have sigmoid shape isotherm curve (Alkali *et al.*, 2009) at low and intermediate water activities, the Equilibrium Moisture Content (EMC) of cowpea flour at the temperature investigated in the present study increased slowly. However, there was a steep rise as water activity increases and fall as it approaches 0.87.

Table 3: Specific regular moisture intake g water / g sample

Relative Humidity	T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_{8-10}
75	0.00	0.02	0.02	0.02	0.03	0.03	0.04	0.03	0.04
77	0.00	0.02	0.03	0.02	0.02	0.03	0.03	0.03	0.03
78	0.00	0.04	0.03	0.03	0.04	0.04	0.04	0.05	0.05
80	0.00	0.04	0.04	0.03	0.04	0.04	0.04	0.04	0.04
81	0.00	0.03	0.06	0.06	0.06	0.04	0.04	0.06	0.06
82	0.00	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.07
83	0.00	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.06
85	0.00	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06
86	0.00	0.05	0.04	0.04	0.04	0.05	0.05	0.05	0.05
87	0.00	0.05	0.02	0.05	0.04	0.05	0.05	0.05	0.05

Table 4: C and n values for Oswin and Halsey equation

Equation	C	N
Oswin	0.27	2.39
Halsey	0.29	2.33

Keys: C = Net heat of sorption n = Number of layers

Using the constants in table 4, the two equations were used to estimate the equilibrium moisture contents of the sample at various points which were compared with the experimental values. The calculated values compared well with the experimental values with high coefficient of determination of fitness of data r = 0.6571. Both the calculated and experimental values were shown in table 5.

Table 5: Comparison between Experimental and calculated value using Oswin equation

Aw	Experimental value	Calculated value
0.75	14.29	13.33
0.77	13.19	13.33
0.78	15.38	13.46
0.80	14.29	13.60
0.81	16.14	13.60
0.82	17.58	13.60
0.83	15.38	13.60
0.85	16.48	13.74
0.86	13.38	13.74
0.87	13.38	13.74

$R^2 = 0.6571$

Table 6: Calculated Me %db for Beans flour at various aw for Oswin equation.

Aw	Me	Aw	Me
0.05	11.02	0.55	12.68
0.10	11.25	0.60	12.81
0.15	11.36	0.65	13.07
0.20	11.47	0.70	13.19
0.25	11.70	0.75	13.46
0.30	11.82	0.80	13.60
0.35	11.94	0.85	13.74
0.40	12.18	0.90	13.87
0.45	12.30	0.95	14.15
0.50	12.55	1.0	14.29

Table 7: Comparison between Experimental and calculated values for Halsey equation

Aw	Experimental value	Calculated value
0.75	14.29	12.81
0.77	13.19	12.81
0.78	15.38	12.94
0.80	14.29	12.94
0.81	16.14	12.94
0.82	17.58	13.02
0.83	15.38	13.03
0.85	16.48	13.20
0.86	13.38	13.20
0.87	13.38	13.20

$R^2 = 0.6762$

Table 8: Calculated Me %db for beans flour at various aw using Halsey equation.

Aw	Me	Aw	Me
0.05	10.38	0.55	12.06
0.10	10.59	0.60	12.18
0.15	10.70	0.65	12.43
0.20	10.91	0.70	12.55
0.25	11.02	0.75	12.81
0.30	11.25	0.80	12.94
0.35	11.36	0.85	13.20
0.40	11.59	0.90	13.33
0.45	11.70	0.95	13.60
0.50	11.94	1.0	13.74

Raw cowpea has sufficient porous structure for water to get access into the interior part without the need for making it into powder. Similarly, a study undertaken by Pappas and Rao (1987) on sorption isotherms of cowpea from 25^{O}C- 70^{O}C shows this. The sorption data obtain were fitted into some known sorption equations in review by Chirife and Iglesias (1978) and by Al-muhtased *et al*., (2002). It is known that the fit becomes better when R-value (R^2) is approaching 1. This is in accordance with the values gotten for Oswin and Halsey equations that gave 0.6571 and 0.6762 respectively. Pappas and Rao (1987) tried to fit their sorption data on cowpea to various proposed isotherm equations such as Henderson, Oswin, Halsey and Chung and pfost. They found out that Henderson and Chung pfost equations are best at 25^0 C, 35^0 C and 45^{0}C, Smith is best at 50^{0}C while Oswin and Halsey are best at 70^{0}C.

However, Chinnan and Beuchat (1985) reported that their sorption data on whole cowpea and flours well fit into smith, Henderson, Haley and Oswin equation. Isotherms depend on temperature. Generally, Moisture Content is expected to decrease with increase in temperature at a given aw which is observed for the product under consideration. The constant C is related to the net heat of sorption (Chirife and Iglesias, 1978). If various temperatures are use, it must be related to the constant to get accurate values. The constant C and n are affected by the state of water in biological food materials. They are used to get large range of data up to saturation pressure. Generally, when using Oswin or Halsey equations for cowpea flours, values for isotherm depends on the a_w chosen and that derived constant depends on temperature (Singh and Ojha, 1974) the **C** constants obtain for Oswin and Halsey are 0.27 and 0.29 while n is 2.39 and 2.33 respectively as shown in Table 10. Basis which can be deduced from Reinaldo *et al* (1978) are that; it is required to specify the a_w range which the equation needs to be determine with using Chirife and Iglesias table (1978) and that moisture sorption isotherms of food gives the hydroscopic properties of the food material under consideration.

4.0 CONCLUSION

From the results of this research work, it can be concluded that Black eye beans have a good functional properties which makes it a good protein source to be use in various food applications. The type II and type III isotherms for beans are consistent with those for other grains found by earlier investigation. The equilibrium moisture content for beans increases with relative humidity. The isotherm equations developed by Halsey and Oswin are able to predict EMC of beans at 30^0C. From the two models used in this study, Halsey is considered to be better as it gave an R-value of 0.6762 which is considered to give a good correlation.

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