



## Determination of the Functional Properties and Moisture Sorption Isotherm of Dried Soybean Curd

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### ABSTRACT

Soybean curd was produced with *ruwan tsami*, lime and aluminum sulphate and dried under the sun at  $34 \pm 2^\circ\text{C}$  to moisture content of 11%. The dried soybean curd was then characterized in terms of functional properties and moisture sorption characteristics. The bulk density of  $0.66\text{kg/m}^3$  for aluminum sulphate,  $0.64\text{kg/m}^3$  for lime and  $0.68\text{kg/m}^3$  for *ruwan tsami* were obtained. The Water Absorption Capacity of aluminum sulphate, lime and *ruwan tsami* were 274.33%, 256.00%, and 252.66% respectively and the Oil Absorption Capacity were found to be 197.67%, 211.00%, and 216.00% respectively. While the Swelling Capacity of the soybean extract for the aluminum sulphate, lime and *ruwan tsami* obtained were 332.47%, 361.33% and 351.13% respectively. The sorption data were fitted into Oswin equation by plotting a linear curve to estimate the constant **c** and **n** of each of the models. These constants were used to extrapolate the equilibrium moisture contents of the samples at various water activity ( $a_w$ ) points. The calculated values were then compared with experimental value and found to compare well and the adsorption Isotherm of the dried soy-curd was plotted and found to correspond to the Flory-Huggins isotherm shape of Type III. The Oswin equation gave high coefficients of determination of fitness of data.

**Keywords:** Soybean curd, Sorption Isotherm, Functional Properties

### INTRODUCTION

Dry powder is an important ingredient in many food products, including reconstituted milk, infant formula, cocoa and high protein drinks, where their solubility is of utmost importance. In Nigeria, *awara* (a soybean based deep fried snack) is increasingly receiving attention due to its high protein content and its function as meat substitute not only because of its availability and low cost, but also for health consideration when animal protein is to be regulated. Development of soybean curd powder for the preparation of *awara* can engender ease and convenience for *awara* preparation, ensure all year availability and help in the industrialization of the *awara* making process for wider distribution to consumers who are not even aware of the product. In so doing, the hydration property of such a powder is central to all these benefits because, for consumers, food powder dissolution will have a direct impact on their perception of the overall quality of the particular product. Hence, various efforts have been made to develop methods to quantify the reconstitution properties of food powders (Chen, 1992). Soybean is being used in various ways in

different homes as soymilk, soy-ogi, soy-daddawa, soy-gari, soy-soup, soy-akara, and hot soy-drink. Escalating prices of protein rich foods continue to force greater percentage of the populace, to eat food supplying less of the required dietary nutrient, and soybean derivatives such as soymilk, soyflour, soy-ogi, soyawara and so on, have been developed and found to be highly nutritious and good substitutes for more conventional food ingredients like melon, cow milk and cowpea (Osho, 2003). *Awara*, also called *Tofu* in Japan and China, 'soybean curd' or *beske* in the Western parts of Nigeria, is popularly consumed because of the various nutritional and medicinal attributes associated with soybeans product such as reduction of cardiovascular disease, osteoporosis, and cancer risks (FDA, 1999). The product is low in calories, rich in essential amino acids, contains beneficial amounts of iron and has no saturated fat or cholesterol (Hou *et al.*, 1997).

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*Awara* is prepared locally by first preparing soymilk and further precipitating the soymilk with a coagulant and then strained to separate the protein concentrate from the whey. The soy protein concentrate is then deep fried to obtain *awara*. This process is normally the most tedious in the preparation of *awara* and can be conveniently skipped at household level when soycurd powder is made available to the household user who will then simply reconstitute the powder to form a curd and the fry. The reconstitution ability of such a curd will depend on the functional hydration properties of the dried curd such as its bulk density, particle size, particle porosity, water absorption capacity and its moisture adsorption phenomena. The eating quality of the fried *awara* in turn will depend on how well the dried curd is reconstituted and the functional properties of the reconstituted curd such as its water imbibition and holding capacity, foaming capacity, oil absorption capacity and the general ability of the reconstituted curd to hold together in a continuous mass without wet segregated particles hanging individually devoid of cohesive forces. Incidentally, water absorption, imbibition and retention by the dried particles are central to this objective. Water absorption by soybeans extract during hydration depends on the time and temperature of immersion during the process (Wang *et al.*, 1979; Sopade and Obekpa, 1990; Coutinho *et al.*, 2009). Mathematical models for fitting hydration data have been developed to predict the required time needed to reach the desired hydration rate at a given temperature and thus, reflect the immersion process dynamic behavior. The models may be either empirical or phenomenological (Maskan, 2002; Resio *et al.*, 2006; Coutinho *et al.*, 2009). Empirical models are used to assess soybean extract hydration data. However, the particularities of food products, whether raw or processed, provide a different behavior to each product subjected to the same process. Moreover, the hydration of soybeans extract is an operation commonly employed in the industry prior to several processing technologies, such as in the manufacturing of soymilk and tofu. Therefore, it is important to validate models describing processes of hydration for different products and cultivars and thus foregrounding other assays that address the same type of product and process.

Commercial dried soybean curd for *awara* preparation is not available in the market and for such to happen the quality standard must be developed as well as direction for use, storage stability and packaging requirements. In this regard, product characterization is the starting point from which standard quality characteristics will be established and then packaging and storage requirements will be specified to maintain quality. This work is therefore designed to characterize dried soybean curd for *awara* and for other applications in terms of the functional properties and sorption characteristics of the dried soybean curd.

## METHODOLOGY

### Production of Dried Soy-Curd

Dried soybean extract was produced from fresh *awara* as described by Shin (2015). Cleaned, sorted soybeans were suspended in water and allowed to soak for 30 minutes. The soaked soybeans were drained off and washed properly with clean water and wet milled using attrition grinder and clean water was added to the slurry soybean, after that a cheese cloth was used to separate the soymilk from the slurry. The slurry was then mixed with some quantity of water which was then filtered to obtain soy milk. The soymilk was made to boil and coagulant of known volume was then added to it and allowed to curdle until there was a separation of the whey from the curd. The mixture (curd and the whey) was poured into a clean and washed cheese cloth and pressed to separate the whey from the curd. The curd was sliced to reduce the size, mashed and then dried until its initial moisture content of 85% was reduced to 6%. Dry curd was then ground to obtain the extract.

### Determination of Water Absorption Capacity

The absorption capacity of water was determined by the standard procedure of AOAC (2010). 2g of the sample powder was weighed into centrifuge tube and 20 ml of distilled water was added, and the tube was shaken and allowed to stand at ambient temperature (25°C) for 30 minutes. It was thereafter centrifuged for 30min at 200rpm and the excess water was decanted by inverting the tubes. The weight of the water bound was determined by variation. Water absorption capacity was calculated using the equation below:

$$\text{Water Absorption Capacity} = \frac{W_2 - W_1}{W_0}$$

where:  $W_0$  is the weight of sample;  $W_1$  is the weight of tube;  $W_2$  is the weight of tube and sample.

#### Determination of Oil Absorption Capacity

The oil absorption capacity was determined by the standard procedure of AOAC (2010). 2g of sample powder was weighed into centrifuge tube and 20ml of oil was added, and the tube was shaken and allowed to stand at ambient temperature (25°C) for 30mins. Then it was centrifuged for 30min at 200rpm and the excess oil was decanted by inverting the tubes. The weight of the oil bound was determined by variation. Oil absorption capacity was calculated using the equation below:

$$\text{Oil Absorption Capacity} = \frac{W_2 - W_1}{W_0}$$

where:  $W_0$  is the weight of sample;  $W_1$  is the weight of tube;  $W_2$  is the weight of tube and sample.

#### Determination of Bulk Density

The bulk density was determined using the standard procedure of AOAC (2010). 20g of sample powder was weighed into 100 ml of a graduated cylinder. The cylinder was then tapped 10 times against the palm; after which, the cylinder was positioned on the table and the final volume was taking. 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.

#### Determination of Swelling Capacity

The swelling capacity was determined by the standard procedure 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. Swelling capacity was calculated using the equation below:

$$\text{Swelling Capacity (\%)} = \frac{W_2 - W_1}{W_0} \times 100\%$$

where:  $W_0$  is the weight of tube after oven heat;  $W_1$  is the weight of tube;  $W_2$  is the weight of sample

#### Determination of Moisture Sorption Isotherm

Moisture sorption property of dried soybean extract was determined using static gravimetric techniques as described by Ariahu *et al.* (2006). Saturated salt solution of sodium chloride (NaCl) was used to obtain different relative humidity environment having water activities between 0.10 - 0.90. The dried soybean extract was placed over the saturated salt solution and kept at ambient temperature. Oswin model was used for determination of the sorption characteristics. The sample was weighed at regular intervals of 1.5rs by the use of a digital weighing balance until a constant weight is obtained. The initial amount of moisture of the dried soybean extract was obtained using drying technique.

#### Statistical Analyses

All analyses were carried out in triplicate ( $n=3$ ) and all data were expressed as mean values  $\pm$  Standard Deviation of Means (SDM). The statistical analysis was conducted as follows: one-way analysis of variance (ANOVA) was done to analyze the significance in the differences of means between the samples; a statistical difference in samples was tested at  $p \leq 0.05$ ; Duncan's Multiple-Range Test (DMRT) was used to differentiate between the mean values.

## RESULTS AND DISCUSSION

The results of the functional properties of the dried soy-curd were shown in Table 1. The result shows that there is no significant difference ( $p \leq 0.05$ ) in the level of Water Absorption Capacity (WAC), Oil Absorption Capacity (OAC), and Swelling Capacity (SC) of the samples, but the level of Bulk Density (BD) increased significantly ( $p \leq 0.05$ ) from  $0.64 \text{ kg/m}^3$  for the dried soybean extract with aluminum sulphate as a coagulant to  $0.66 \text{ kg/m}^3$  for the dried soybean extract with lime as a coagulant and  $0.68 \text{ kg/m}^3$  for the dried soybean extract with *ruwan-tsami* (corn liquor).

Table 2 shows the result of moisture adsorption of dried soy-curd maintained at different relative humidity values. The result shows that the equilibrium moisture content (dry basis) decreased between the relative humidity range of 75% - 82% and increased at 83% relative humidity and above. The results also revealed that after 10.5hrs of adsorption, constant weight was attained indicating the equilibrium moisture

content at that relative humidity. Contrary to popular expectation that at higher RH values adsorption mechanism is supposed to be faster and equilibrium attained faster. It was observed that at all the RH values, the samples attained equilibrium after about 10hrs of adsorption. This may imply that for dried soy-curd, adsorption may be a function of the cellular matrix and the bulk density of the material rather than the RH of the environment. This observation would then

have serious impact on the packaging and storage of dry soy-curd and its reconstitutionability.

This observation becomes more obvious when the regular specific moisture uptake (Table 3) is considered. As RH increases, the specific amount of water adsorbed by the soy-curd decreases up to 82% RH before picking up at 83% RH and above.

Table 1: Functional properties of dried soybean extract with different coagulant

| Samples | WAC (%)                   | OAC (%)                   | BD (kg/m <sup>3</sup> ) | SC (%)                    |
|---------|---------------------------|---------------------------|-------------------------|---------------------------|
| A       | 274.33±7.64 <sup>a</sup>  | 197.67±43.11 <sup>a</sup> | 0.66±0.01 <sup>b</sup>  | 332.47±29.41 <sup>a</sup> |
| B       | 256.00±37.75 <sup>a</sup> | 211.00±15.00 <sup>a</sup> | 0.64±0.01 <sup>c</sup>  | 361.33±16.58 <sup>a</sup> |
| C       | 252.66±24.66 <sup>a</sup> | 216.00±5.00 <sup>a</sup>  | 0.68±0.01 <sup>a</sup>  | 351.13±13.68 <sup>a</sup> |

Key:

Sample A – Dried soybean extract with aluminium sulphate as a coagulant; Sample B – Dried soybean extract with lime as a coagulant; Sample C– Dried soybean extract with *ruwan-tsami* (corn liquor)

Table 2: Weight Increase in Gram at Regular Time Interval

| % Relative Humidity | Time  |        |       |        |       |        |       |                    | %M <sub>e</sub> (d. b) |
|---------------------|-------|--------|-------|--------|-------|--------|-------|--------------------|------------------------|
|                     | 0     | 1.5hrs | 3hrs  | 4.5hrs | 6hrs  | 7.5hrs | 9hrs  | 10.5hrs to 13.5hrs |                        |
| 75                  | 10.00 | 10.33  | 10.36 | 10.53  | 10.73 | 10.40  | 10.33 | 10.46              | 11.28                  |
| 77                  | 10.00 | 10.26  | 10.30 | 10.86  | 11.23 | 10.23  | 10.30 | 10.30              | 9.57                   |
| 78                  | 10.00 | 10.20  | 10.30 | 11.03  | 11.36 | 10.30  | 10.23 | 10.23              | 8.83                   |
| 80                  | 10.00 | 10.30  | 10.26 | 11.23  | 11.53 | 10.30  | 10.26 | 10.26              | 9.15                   |
| 81                  | 10.00 | 10.13  | 10.16 | 10.30  | 11.56 | 10.13  | 10.16 | 10.16              | 8.09                   |
| 82                  | 10.00 | 10.13  | 10.13 | 10.40  | 10.63 | 10.16  | 10.16 | 10.16              | 8.09                   |
| 83                  | 10.00 | 10.40  | 10.43 | 10.46  | 10.43 | 10.40  | 10.43 | 10.46              | 11.28                  |
| 85                  | 10.00 | 10.13  | 10.13 | 10.30  | 10.16 | 10.16  | 10.20 | 10.20              | 8.51                   |
| 86                  | 10.00 | 10.36  | 10.46 | 10.66  | 10.66 | 10.46  | 10.43 | 10.46              | 11.28                  |
| 87                  | 10.00 | 10.06  | 10.23 | 10.46  | 10.46 | 10.20  | 10.16 | 10.16              | 8.09                   |

Values are means of triplicate readings

Table 3: Specific Regular Moisture Uptake in Grams (Weight at time T – Initial weight)

| % Relative Humidity | 0 | 1.5hrs | 3hrs | 4.5hrs | 6hrs | 7.5hrs | 9hrs | 10.6hrs |
|---------------------|---|--------|------|--------|------|--------|------|---------|
| 75                  | 0 | 0.33   | 0.36 | 0.53   | 0.73 | 0.40   | 0.33 | 0.46    |
| 77                  | 0 | 0.26   | 0.30 | 0.86   | 1.23 | 0.23   | 0.30 | 0.30    |
| 78                  | 0 | 0.20   | 0.30 | 1.03   | 1.36 | 0.30   | 0.23 | 0.23    |
| 80                  | 0 | 0.30   | 0.26 | 1.23   | 1.53 | 0.30   | 0.26 | 0.26    |
| 81                  | 0 | 0.13   | 0.16 | 0.30   | 1.56 | 0.13   | 0.16 | 0.16    |
| 82                  | 0 | 0.13   | 0.13 | 0.40   | 0.63 | 0.16   | 0.16 | 0.16    |
| 83                  | 0 | 0.40   | 0.43 | 0.46   | 0.43 | 0.40   | 0.43 | 0.46    |
| 85                  | 0 | 0.13   | 0.13 | 0.30   | 0.16 | 0.16   | 0.20 | 0.20    |
| 86                  | 0 | 0.36   | 0.46 | 0.66   | 0.46 | 0.43   | 0.43 | 0.46    |
| 87                  | 0 | 0.06   | 0.23 | 0.46   | 0.20 | 0.20   | 0.16 | 0.16    |

Values are means of triplicate reading

With the experimental values of  $M_e$ , linearized form of the Oswin equations were used to calculate the constants C and n representing the number of layers and the net heat of sorption (Chirife and Iglesias, 1978) of the dry soy-curd respectively. These constants for both the equations are shown in Table 4. The constant C and n are affected by the state of water in biological food materials. They are used to get wide range of data up to saturation pressure.

Table 4: C and n values for Oswin and Henderson

| Equation | C     | n     |
|----------|-------|-------|
| Oswin    | 2.685 | 0.317 |

These constants were then used to extrapolate the data up to the saturation pressure and down to the lower pressure region. However, the limitation of this method is that the values of the parameters depend on the region of the isotherm used for the evaluation and also the values of the constants are temperature dependent (Chirife and Iglesias, 1978). Specifications are therefore required for the range of  $a_w$  and the temperature of the sorption environment. However, this is in line with the conditions of sorption proposed by Reinaldo *et al.* (1978) and concluded that within these limits most isotherm equations, including Oswin and Henderson equations have reasonably good fit, and hence the values obtained here are reliable.

Table 5: Comparison between Calculated value and Experimental Values of  $M_e$  by Oswin Equation

| $a_w$ | Calculated $M_e$ | Experimental $M_e$ |
|-------|------------------|--------------------|
| 0.75  | 18.73            | 11.28              |
| 0.77  | 18.92            | 9.57               |
| 0.78  | 18.92            | 8.83               |
| 0.80  | 19.11            | 9.15               |
| 0.81  | 19.11            | 8.09               |
| 0.82  | 19.11            | 8.09               |
| 0.83  | 19.30            | 11.28              |
| 0.85  | 19.30            | 8.51               |
| 0.86  | 19.49            | 11.28              |
| 0.87  | 19.49            | 8.09               |

The above comparison revealed that calculated  $M_e$  values are much higher than the experimental values. This may be due to the temperature of sorption as it is established that some sorption models are better suited at low temperatures while others estimate better at high temperatures (Akubor and Egbekun, 2017) as it

is also known to vary with different foods, processing methods and temperature (Akubor and Egbekun, 2017; Palou *et al.*, 1997). Pappas and Rao (1987) fitted their sorption data on cowpea to various proposed isotherm equations including Henderson, Oswin, Halsey and Chung and pfost. They found out that Henderson and Chung pfost equations are best at 25°C, 35°C and 45°C, Smith is best at 50°C while Oswin and Halsey are best at 70°C, the fact that explained why Oswin equation predicted large  $M_e$  values at 30°C observed in this work.

Table 6: Calculated  $M_e$  for Dried Soy-curd by Oswin Equation

| $a_w$ | Calculated $M_e$ |
|-------|------------------|
| 0.05  | 15.03            |
| 0.10  | 15.18            |
| 0.15  | 15.49            |
| 0.20  | 15.64            |
| 0.25  | 15.96            |
| 0.30  | 16.28            |
| 0.35  | 16.44            |
| 0.40  | 16.78            |
| 0.45  | 16.95            |
| 0.50  | 17.29            |
| 0.55  | 17.64            |
| 0.60  | 17.81            |
| 0.65  | 17.99            |
| 0.70  | 18.36            |
| 0.75  | 18.73            |
| 0.80  | 19.11            |
| 0.85  | 19.30            |
| 0.90  | 19.69            |
| 0.95  | 19.89            |
| 1.0   | 20.29            |

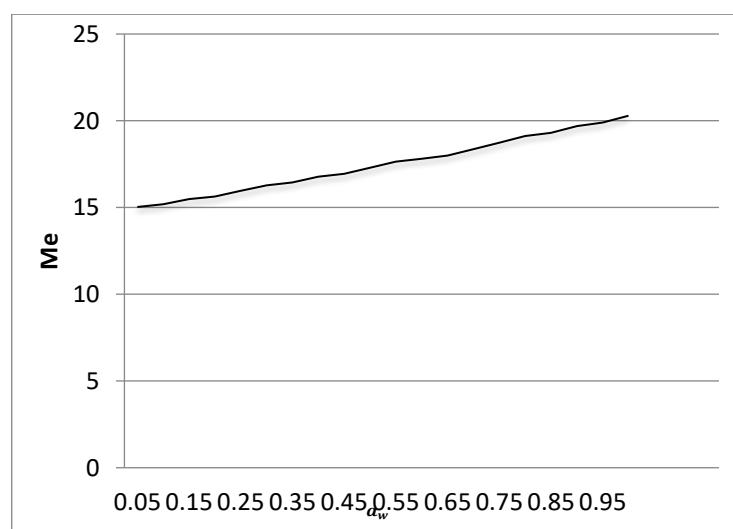


Fig. 1: Adsorption Isotherms of Dried Soy-curd by Oswin Equation

The adsorption isotherm of dried soy-curd at room temperature (30°C) as shown in Fig. 1 exhibited a Flory-Huggins isotherm shape which is described as Type III of classification made by Bruenaur (Ariahu *et al.*, 2006). Although, most biological food product have sigmoid shape isotherm curve. It is understood that the fit becomes better when the R-value ( $R^2$ ) is approaching 1. This corresponds to the values obtained here for Oswin equation that gave 0.712. However, Chinnan and Beuchat (1985) reported that their sorption data on flours well fit into Smith, Henderson, Halsey and Oswin equation depending on the sorption temperature. Generally, equilibrium moisture content is predicted to decrease with increase in temperature in a given  $a_w$  which is observed here for the dried soy-curd.

### Conclusion

The dried soy-curd recorded functional properties comparable to powdered products that require reconstitution indicating that upon reconstitution, adequate flow properties and water retention can be obtained that can compare well with fresh soy-curd. Moisture adsorption by the dried soy-curd was characterized by Oswin equation and was observed that the equation can only be used with reservations to predict equilibrium moisture content of the product at 30°C. As expected, the calculated values for the model increased with water activity. The sorption curves conform to the Type III classification of sorption curves typical of biological materials. The R-values for the two equations 0.712 for Oswin equation indicative of a good fit.

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