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Moisture sorption isotherms and storage study of spray dried tamarind pulp powder

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ABSTRACT

Moisture adsorption isotherms and storage study of spray dried tamarind pulp powder were evaluated in this work. Adsorption isotherms of tamarind pulp powder were determined at four different temperatures (20, 30, 40 and 50 °C) using a gravimetric technique. The sorption isotherms were found to be typical type II sigmoid. The experimental data obtained was fitted to several mathematical models viz. two-parameter (BET, Oswin, Smith, Caurie, and Iglesias and Chirife), and three-parameter (GAB) relationships. A non-linear least square regression analysis was used to evaluate the model constants. The GAB followed by Oswin model best fitted the experimental data. Changes in physicochemical properties of tamarind pulp powder were evaluated during storage (at 0, 1, 2, 3, 4, 5 and 6 months), using three different packaging materials (low density polyethylene, LDPE; aluminum laminated polyethylene, ALP and glass). Color parameters, moisture content, titratable acidity, bulk density and flowability of the powder varied to different extent during storage, depending on the type of packaging material used. Compared to other packaging materials, powder packed in LDPE showed considerable changes in physicochemical properties during storage. The magnitude of the change in physicochemical properties of the powder measured during storage suggests that glass is best for long term storage of tamarind pulp powder.

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1. Introduction

Water sorption isotherms are considered important thermodynamic tools to determine the interaction between water and food components. They represent the relationship of the equilibrium moisture content of a food product with the relative humidity of its surrounding environment at a particular temperature and provide useful information for food processing operations such as drying, packaging and storage [1,2]. A moisture sorption isotherm can be used to predict the amount of water that a material will hold if it is exposed to air at a certain relative humidity. This moisture content is dependent on the temperature and the environmental relative humidity, as well as on the composition of the material [3]. The sorption isotherms are commonly presented by mathematical models based on empirical and/or theoretical criteria. In the literature, a large number of isotherm models are available which can be categorized into various groups; kinetic models based on an absorbed monolayer of water (BET model), kinetic models based on a multi-layer and condensed film (GAB model), semi-empirical (Halsey model) and purely empirical models (e.g. Oswin and Smith models). The moisture sorption isotherms are unique for every material and must be evaluated experimentally.

Fruit juice and pulp powders are valuable materials in terms of transportation, packaging, storage and shelf life, compared with their liquid counter parts. Spray drying is one of the common technique used for production of powders from liquid solutions and suspensions. Tamarind pulp in powder form is one of the important tamarind product. However due to high amount of sugars and acids in tamarind pulp, higher significant product loss occurs during spray drying because of the stickiness of the powder. Hence to overcome the stickiness problem, drying aids are added during spray drying of tamarind pulp [4,5]. Besides this, physicochemical properties of spray dried powder are affected by the conditions used during powder production and storage. In our previous study, effect of processing conditions on physicochemical properties of spray dried tamarind pulp powder was studied [5], however there is no investigation about the quality changes of tamarind pulp powder during storage.

Thus, the objective of the present study was to provide experimental data for sorption characteristics of spray dried tamarind pulp powder in order to model the sorption isotherms using selected models and to evaluate the changes in physicochemical properties of spay dried tamarind pulp powder during storage.

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2. Materials and methods

2.1. Sample preparation

Tamarind fruit pods were deshelled and soaked in water in the ratio 1:2.5 under optimum conditions of 33 min soaking time and 39 °C soaking temperature [6]. The mixture was then homogenized and sieved to separate fiber, rags and seeds from the pulp. The pulp was passed through three layers of muslin cloth to obtain fine pulp.

2.2. Spray drying of tamarind pulp

A tall type laboratory scale spray dryer (S.M. Scientech, Calcutta, India) with cocurrent regime (flow of feed spray and drying air in same direction) and a two-fluid nozzle (inside diameter of 0.5 mm) atomizer was employed for spray drying process. Feed was metered into the dryer by means of a peristaltic pump. Based on our previous study, the derived optimum conditions for spray drying of tamarind pulp were 25% carrier (soya protein isolate) concentration, 170 °C inlet air temperature and 400 ml/h feed flow rate [5] Feed temperature, compressor air pressure and blower speed were kept at 25.0 ± 0.5 °C, 0.06 MPa and 2300 rpm, respectively. After the completion of the experiment, the powder was collected from the cyclone and cylindrical parts of dryer chamber by lightly sweeping the chamber wall as proposed by Bhandari et al. [7].

2.3. Determination of sorption isotherms

Sorption isotherms were determined by the gravimetric method. Eight saturated salt solutions were prepared in order to provide different relative humidity values. The salt solutions used and the corresponding relative humidities at different temperatures are given in Table 1 [8]. Triplicate samples (1 g) of freshly prepared spray dried tamarind pulp powder were placed in previously weighed alumunium dishes. The samples were then kept in desiccators over the saturated salt solution of known relative humidity. The desiccators were placed in temperature-controlled cabinets maintained at 20, 30, 40 and 50 °C (±1 °C) and the samples were allowed to equilibrate until there was no distinct weight change (±0.0001 g). A test tube containing thymol was placed inside the desiccators with high relative humidity to prevent mold growth during storage. The required time period for equilibration was about 3–4 weeks. The total time for removal, weighing, and putting back the sample in the desiccator was about 30 s. This minimized the degree of atmospheric moisture sorption during weighing. The equilibrium moisture content was determined in a vacuum oven, at 70 °C until constant weight was obtained [9]. The measurements were recorded as the mean of triplicates samples.

2.4. Storage study

Freshly prepared tamarind pulp powder samples (15 g) were packed in three different packaging materials (low density polyethylene, LDPE; aluminum laminated polyethylene, ALP and glass) and placed in desiccators filled with saturated solution of Magnesium nitrate in order to provide a constant relative humidity of 53% during the storage period. The desiccators were then stored at 25 ± 1 °C, representing room temperature. The powder samples were periodically analyzed (at 0, 1, 2, 3, 4, 5 and 6 months) for different physicochemical properties (color, moisture content, acidity, bulk density and flowability).

Table 1
Relative humidities of selected saturated salt solutions at different temperatures.

Salt	Relative humidity (%)			
	20 °C	30 °C	40 °C	50 °C
Lithium chloride	11.3	11.3	11.2	11.1
Potassium acetate	23.1	21.6	20.8	20.4
Magnesium chloride	33.1	32.4	31.6	30.5
Potassium carbonate	43.2	43.2	40.0	38.5
Magnesium nitrate	54.4	51.4	48.4	45.4
Potassium iodide	69.9	67.9	66.1	64.5
Sodium chloride	75.5	75.1	74.7	74.4
Potassium chloride	85.1	83.6	82.3	81.2

2.4.1. Color measurement

The color of the powder samples was determined by using a color spectrophotometer (CM-3600d, Konica Minolta). The results were expressed in terms of Hunter color values of L*, a*, and b*, where L* denotes lightness/darkness, a* redness/greenness, and b* yellowness/blueness.

2.4.2. Moisture content

The moisture content (%) of the powder samples was determined according to AOAC method [9]. About 2 g of the powder sample was taken in a petriplates and dried in a vacuum oven at a temperature of 70 °C until a constant weight was obtained. The samples were analyzed in triplicates and the mean was recorded.

2.4.3. Titratable acidity

The titratable acidity (%) of the powder sample was determined by titration with standardized 0.1 N NaOH to the phenolphthalein end point, according to the method described by Rangana [10]. Titratable acidity was measured in terms of tartaric acid. The samples were analyzed in triplicates and the mean value was calculated.

2.4.4. Bulk density

For the determination of loose bulk density a known quantity of powder sample was freely poured into a 10 ml graduated cylinder (readable at 0.1 ml) and the volume occupied was noted and then used to calculate bulk density (weight/volume).

2.4.5. Powder flowability

Powder flowability was measured in terms of cohesive index by using a Powder flow analyzer attached to a texture analyzer (Stable Micro Systems, UK). A fixed powder volume of 25 ml was poured into the cylindrical vessel of the analyzer prior to testing. During the test, the blade of the analyzer took a downward and then upward movement for three cycles inside the cylinder, corresponding to three compaction and decompaction phases. The force–displacement curve was thus generated by the system, exhibiting the force exerted on the cylinder bottom due to blade movement and powder displacement. A cohesion coefficient (g.mm) was derived by Texture Exponent software (Stable Micro System, UK) through integrating the negative area underneath the curve during the decompaction cycle. The cohesion index (mm) was defined as the ratio of the negative area under force displacement curve to the sample weight.

2.5. Sensory evaluation

A panel comprising of seven trained judges did sensory evaluation of tamarind pulp powder after a regular interval of one month storage period by using 9-points hedonic scale scorecard.

2.6. Analysis of sorption data

The equilibrium moisture content of the powders for each temperature was plotted against the corresponding water activity (relative humidity/100) to produce the sorption isotherms. Six different mathematical models presented in Table 2 were used to fit to the experimental data using regression analysis. The curve fitting and regression analysis were performed using Statistica. V.8. (Statsoft, India Pvt. Ltd. New Delhi). The goodness of the fit of each model was evaluated in terms

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