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Moisture Sorption Isotherm and Shelf Life of Pumpkin and Arrowroot Starch-based Instant Porridge

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Abstract. Pumpkin and arrowroot starch instant porridge is a food product that is convenient to serve and appetizing to the panelist. Pumpkin and arrowroot starch instant porridge is a dry product that contains sugar; therefore, it is sensitive to moisture change during storage. Developing further product requires investigation on the proper storage condition and product stability during shelf life. Therefore, it is important to evaluate the different patterns of moisture absorption during storage. Moisture sorption isotherm of pumpkin and arrowroot starch-based instant porridge was determined using static gravimetric method at 25°C. The sample was reserved in a room RH controlled by different types of water activity (aw) from 0.07 to 0.97 to reach a balance water content. Moisture absorption was fitted to the GAB model (Guggenheim-Anderson-de Boer). The permeability of the 0.08 mm polypropylene plastic container and the shelf life of pumpkin and arrowroot starch-based instant porridge were investigated according to treatment with an accelerated technique. The result showed that the moisture sorption isotherm of pumpkin and arrowroot starch-based instant porridge showed a sigmoid curve. The shelf life of pumpkin and arrowroot starch-based instant porridge that was packed in 0.08 mm polypropylene plastic containers at 70% RH was 178.60 days or 5.96 months.

INTRODUCTION

The quality of food products preserved by dehydrating depends on the physical, chemical and microbiological stability. Pumpkin and arrowroot starch instant porridge is a dry product that is prone to detrimental factors such as water which may damage the product on the shelf. The main contributor to the changing characteristic is water activity in the food product [1]. Food stability is mainly determined by the characteristic of water sorption and moisture sorption isotherm (MSI) which reflect the structure and behavior of water on the surface and inside the food product [2]. MSI curve demonstrates the relationship between and water activity (aw) and water balance of food products [3].

Pumpkin and arrowroot starch instant porridge made of 5:1 pumpkin and arrowroot starch processed in a drum drier at 1.5 rpm speed was the most palatable according to panelist [4]. The porridge potentially reduces blood sugar and cholesterol level; therefore, it is suitable for people with diabetes mellitus and high cholesterol.

Gelatinization in the porridge making process would increase porosity which makes the ingredients more hygroscopic. High sugar in pumpkin contributes to the physical change of the instant porridge – it absorbs steam then clots. Pumpkin and arrowroot starch instant porridge has low water content i.e. 5.81% [4]. Damage in instant porridge is mostly related to the change in texture or the stability of the oxidation process [5]. Texture change is correlated with water content. Protein may undergo oxidation to form intermolecular disulfide bonds that could inhibit the starch

swelling, and lipid hydrolysis occurs to form peroxide and carbonyl compound that is responsible for the off-flavor in rice [6]. The damage is attributed to water activity and water content. Accordingly, it is important to evaluate the water adsorption process when the product is being stored. Water adsorption of a product is described from the MSI curve.

MSI curve demonstrates water activity-water balance relationship at certain temperature and pressure [7]. This study used the GAB model (Guggenheim-Anderson-de Boer) because it could articulate water adsorption at a broader range of a_w between 0.10 and 0.95 [8]. Additionally, the GAB equation demonstrates a sound mathematical function to breakdown water absorption into MSI curve, and the model constants theoretically describes the phenomena. Peng *et al.* stated that GAB equation is prevalent because the deviation is low (<10%) [9].

This study was conducted to determine the moisture sorption isotherm curve and shelf life of pumpkin and arrowroot starch instant porridge packed in a polyethilen 0.08 mm polyethylene plastic container.

MATERIALS AND METHODS

The material of this study was pumpkin and arrowroot starch instant porridge with the ratio 5:1 processed in a drum drier at 1.5 rpm speed and 1 atm vapor pressure of steam. The saturated salts for this study included NaOH, LiCl₂, KF, MgCl₂, K₂CO₃, NaBr, NaNO₂, NaCl, KCl, BaCl₂, and K₂SO₄. The equipments for this study were oven drier, jars, 0.08 mm polypropylene plastic 9 x 7 cm² and a set of tool for moisture sorption isotherm.

Determine MSI

The pattern of pumpkin and arrowroot starch instant porridge moisture sorption isotherm was determined using Ranganna method at 25°C. Pumpkin and arrowroot starch instant porridge was tested 11 times with two replicates each. Two grams of pumpkin and arrowroot starch instant porridge was placed in a measuring bottle, then the bottle was oven-dried and weighed to reach the constant weight. Two measuring bottle and the constant sample were put into a jar for two replicates, then the jar was kept in a 25°C room. The sample was weighed every two days to obtain constant weight. The moisture sorption pattern was determined using 11 saturated salt solution (Table 1.) which formed 7.6 to 90.3% relative humidity. The tool to measure relative humidity (*Equilibrium Relative Humidity*, ERH) was hygrometer (*Barigo Hair Hygrometer*). To determine water adsorption by instant porridge, ERH and water balance data were transformed into a correlation graph between A_w and the water balance [7]. The analysis of water content in the rice sample was subject to static gravimetry method [10].

TABLE 1. Saturated salt solutions

ERH (%)	a_w	Saturated salt
7.60	0.076	NaOH
11.20	0.112	LiCl ₂
27.30	0.273	KF
32.70	0.327	MgCl ₂
43.80	0.438	K ₂ CO ₃
57.70	0.577	NaBr
63.70	0.637	NaNO ₂
75.00	0.750	NaCl
84.30	0.843	KCl
90.30	0.903	BaCl ₂
97.10	0.971	K ₂ SO ₄

GAB model was applied in this study [7]. Water balance level at certain a_w was plotted into GAB equation as in equation 1 where M is water balance (% db), M_m is monolayer water content (%), a_w is water activity, C is the constant energy adsorption of monolayer water, and K is the constant energy of multilayer water (above monolayer water). The precision between the selected mathematical models with experimental data was determined using the relative mean deviation (% RMD). A sound precision is when RMD value below 10% [11].

Package Permeability and Shelf Life of Pumpkin and Arrowroot Starch Instant Porridge

Permeability test of the package against water vapor was conducted at 25°C and 90% relative humidity. A preheated 25 g desiccant was put into a 0.08mm polypropylene plastic bag, and the weight was measured every two days for 30 days. At this stage, the air pressure in the atmosphere (Pout) was 21.380 mmHg while inside the package was assumed zero. The weight change data were transformed into a linear equation to calculate the permeability demonstrated in the coefficient regression value (b1).

The standard maximum rice water was 15% (bb) which reflected the critical condition in the storage. The shelf life of pumpkin and arrowroot starch instant porridge was determined by placing 25g instant porridge into a 0.08 mm polypropylene plastic container 9 x 7 cm² at 25°C with 90% RH, and the weight gain was measured every two days for 30 days. The shelf life was calculated by factoring the package permeability against water vapor [12].

Data Analysis

The obtained data were subject to descriptive statistics using Microsoft Excel and SPSS for Windows to estimate the coefficient values in linear or quadratic equations.

RESULTS AND DISCUSSION

The Curve of Moisture Sorption Isotherm

The obtained water balance data were transformed into a correlation graph between a_w and water content (% db). The MSI curve of pumpkin and arrowroot starch instant porridge was presented in Figs. 1 and 2. In general pumpkin and arrowroot starch instant porridge shows ISL curve tendency to isotherm type II – a sigmoid leaning to the right. A high increase in water level was observed in an area where a_w was high (>0.75). However, a high water increase was not followed by a significant increase of water activity. On the contrary, in low a_w area (<0.75) the water level increase was relatively small-stimulating a significant increase of a_w .

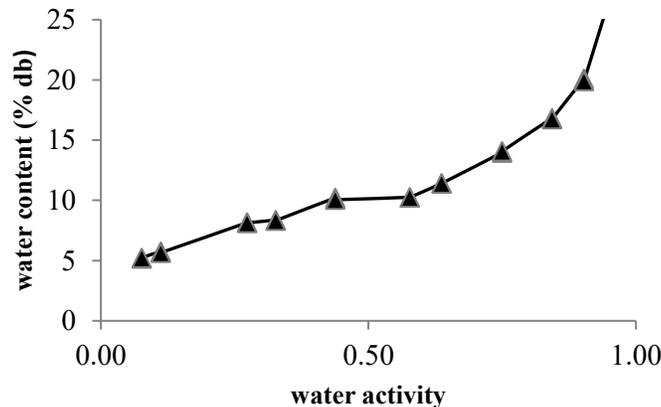


FIGURE 1. Moisture sorption isotherm curve of pumpkin and arrowroot starch instant porridge treatment

Figures 1 and 2 show that moisture sorption isotherm curve of pumpkin and arrowroot starch instant porridge in the experiment was almost equal to the predicted GAB in nearly all water activity. Similarly, Peng *et al.* [9] stated that the isotherm curve of corn starch was more similar using GAB model. The GAB model could represent 0.0 to 0.94 water activity, and evaluation of grains showed that the models demonstrated a high validity [13]. Some advantages of GAB model include the theoretical background compared to BET (theoretical) that could describe the isotherm sorption in almost all food products, and the a_w 0.1 < a_w < 0.9 shows a simple mathematical equation.

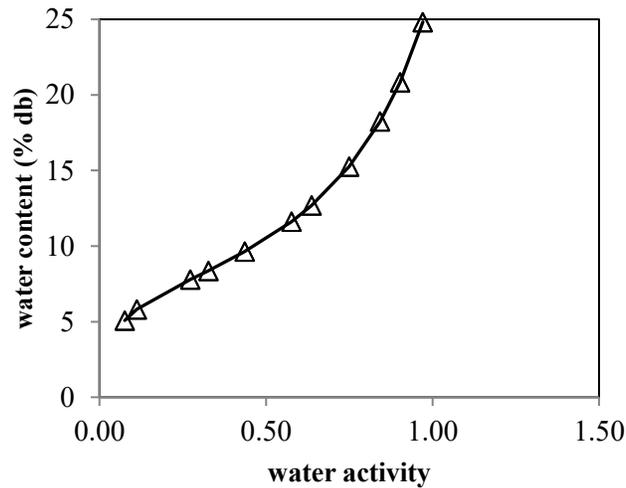


FIGURE 2. Moisture sorption isotherm curve from the GAB equation of pumpkin and arrowroot starch instant porridge

Based on the calculation using GAB equation, the α , β , and γ constant, the monolayer water (Mm), multilayer energy (K), and the monolayer water energy adsorption (C) are presented in Table 2.

TABLE 2. α , β , and γ constant, monolayer water (Mm), multilayer energy (K), and the monolayer water energy adsorption (C) from GAB equation

Sample	data	α	β	γ	Mm (% db)	C	K	R	RMD (%)
Instant porridge	18	0.0050	0.1393	-0.1070	6.81	39.24	0.75	0.86	7.69

Monolayer water of pumpkin and arrowroot starch instant was 6.81% db. It was similar to 0.040-0.059 g/g db of monolayer water in the cracker and 0.032-0.160 g/g db in the starchy product by [8]. The prediction of monolayer water is crucial because food product seldom experiences damage when the water level below the monolayer water is very low. Also, water-holding in monolayer water is very strong which better maintains rice stability than products with water level below the monolayer [14]. Water level in the monolayer was primary bound water that could not function as a solvent of plastic. The primary bound water is a part of solid because the water was absorbed on the active side of solid polar [15]. Jirasatid *et al.* stated that the BET model is more efficient to estimate the value of monolayer water that is adsorbed on the surface [13]. Aini *et al.* reported that the pioneer cornflour had a 6.48 monolayer water [16].

Table 2 shows that the bound water in the monolayer of pumpkin and arrowroot starch instant porridge was 6.81% db due to the gelatinization process which increased porosity. Previous studies demonstrated that water molecule diffusion was significantly affected by the physical structure of the product. The coefficient diffusion increased as the porosity of the starchy product [17], and cake [18] increased. However, Lazouk *et al.* reported that the increasing density suggested the decreasing porosity that may improve the shelf life [19]. This condition was parallel to the C value (adsorption energy constant) and showed the necessary water-binding energy in the monolayer. C value of pumpkin-arrowroot starch instant porridge was 39.24.

K constant reflects the multilayer water constant (above the monolayer) and this study reported 0.75 K constant of pumpkin and arrowroot starch instant porridge. Table 2 demonstrates that the mean deviation value indicates the GAB model well describes the adsorption pattern of pumpkin and arrowroot starch instant porridge because the RMD was below 10% (7.69 %). Additionally, the coefficient correlation was relatively sound. Furthermore, [20] argued that the GAB equation could better explain ISL forming sigmoid pattern in area $k \leq 1$ and $5.67 \leq C \leq \infty$; MSI is not sigmoid outside these areas. The GAB equation could explain the adsorption pattern of *Amaranthus* seeds [20,21].

Water balance was calculated using the GAB equation at different levels of RH as shown in Table 3. The calculation showed that the bigger the RH, the bigger water balance. The secondary bound water that showed the secondary and tertiary borders in pumpkin and arrowroot starch instant porridge was 25.40% db.

TABLE 3. Balance water content, secondary bound water and tertiary bound water

Sample	Balance water content (% db)			Bound water content	Tertiary bound water content
	RH 75%	RH 80%	RH 85%		
Instant porridge	15.26	16.74	18.52	6.81-25.40	>25.40

Shelf Life

Water vapor permeability of a package is the speed or rate of water vapor transmission through a unit area of a package with a level surface and at a certain thickness as a result of different water vapour pressure inside the package and on the surface at a particular temperature and RH. Table 4 shows that the package permeability and permeability constant of the package for pumpkin and arrowroot starch instant porridge was 0.0290 and 0.001356, respectively.

TABLE 4. Water vapour permeability of primary package of instant porridge polypropylene plastic 0.08 mm

Sample	Permeability ^a	Permeability constant ^b
Instant Porridge	0.0290	0.001356

^a g water/ day. Bag . 21.38 mm Hg

^b g water vapour/day. bag. mm Hg

The predicted/calculated shelf life of pumpkin and arrowroot starch instant porridge that was packed in a 0.08 mm polypropylene bag at 70% RH was 178.60 days or 5.95 months.

CONCLUSIONS

Pumpkin and arrowroot starch instant porridge had a sigmoid, type II moisture sorption isotherm. GAB approach demonstrated that the monolayer water was 6.81% db. The critical characteristic of pumpkin and arrowroot starch instant porridge was clotting due to water vapor absorption. The predicted shelf life of pumpkin and arrowroot starch was 178.60 days or 5.95 months when packaged with a 0.08 mm polypropylene plastic bag and stored at 25°C and 70% RH.

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