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Moisture sorption studies on onion powder

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Abstract

Moisture sorption studies were conducted on three samples of onion powders, i.e. freeze-dried, vacuum shelf-dried and through flow-dried onions. The data obtained for texture (flowability) and per cent moisture were used in determining critical moisture levels. The monolayer moisture contents, corresponding to Brunauer Emmett Teller (BET) theory were taken as the safe minimum moisture levels in onion powder. The moisture content values (moisture-free basis), which correspond to a monomolecular layer of adsorbed water computed by BET equation, were 2.09, 1.96 and 1.94%, for freeze-dried, vacuum shelf-dried and through flow-dried onion powders, respectively. This study on initial and critical moisture levels of dehydrated onion powders helps in the selection of the packaging materials for storage. © 2002 Elsevier Science Ltd. All rights reserved.

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1. Introduction

Moisture sorption isotherms are useful thermodynamic tools for determining interactions of water and food substances, and provide information to assess food processing operations, such as drying, mixing, packaging, and storage. Sorption isotherms can also be used to investigate structural features of a food product, such as specific surface area, pore volume, pore size distribution and crystallinity. Such data can be used for selecting appropriate storage conditions, and packaging systems that optimize or maximize retention of aroma, colour, texture, nutrients and biological stability (Labuza, Kaanane, & Chen, 1985; Okos, Narsimhan, & Singh, 1992; Rizvi, 1995). The beneficial health effects of antioxidant flavonoids are of increasing interest to food manufacturers. The major sources of dietary flavonoids in many countries are tea, onions, and apples (Hertog et al., 1995). Onions contain high amounts of flavonoids (Ewald, Fjelkner-Modig, Johansson, Sjöholm, & Åkesson, 1999; Hertog, Hollman, & Katan, 1992; Hertog et al., 1995). These flavonoids have an antioxidative effect (Bros, Heller, Michel, & Saran, 1990), and they prevent or delay diseases such as cancer and cardiovascular disease (Block, 1992; Renaud & de Lorgeril, 1992). Dehydrated onion has great commercial value due to its culinary and medicinal properties in "Nutraceuticals". However, moisture sorption data on onion powder are very rare in published literature. This paper presents data on sorption characteristics of onion powders prepared by different drying techniques, over a range of water activities.

2. Materials and methods

The fresh onions (*Allium cepa* L.) *Allium aggregatium*, Bangalore small, a variety grown at the experimental farm of University of Agricultural Science, Bangalore, were used in the study. The onion bulbs were hand-peeled and mechanically sliced into 3–3.5 mm thick slices, and dehydrated in a pilot scale freeze-dryer (Hull Corporation, USA), vacuum shelf-dryer and through flow-dryer, to a final moisture content of approximately 3%, moisture-free basis (MFB) or less, as follows:

> Freeze-drying: freezing temperature −30 °C, drying temperature 50 °C, vacuum 0.15–0.20 mm Hg, freezing time 4 h, drying time 20 h, and 24 h total drying time including freezing.

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Vacuum shelf-drying: drying temperature 80±1 °C, vacuum 510 mm Hg, and 6 h total drying time.
Through flow-drying: stationary bed, inlet air temperature 75±1.5 °C, outlet air temperature 65±1.5 °C and 6 h total drying time.

All solvents and chemicals were of AnalaR grade, and were purchased from Sigma Chemical Co. (St. Louis, MO).

The moisture contents of fresh and dehydrated onions were determined by the vacuum oven method (AOAC, 1990). The total soluble solids and pyruvic acid analyses in onions were performed according to Schwimmer and Guadagni (1962), with slight modifications according to Wall and Corgon (1992). Dehydrated onions were milled to yield a 30 mesh powder. Moisture sorption isotherms were determined by the method described by Hayakawa, Matas, and Hwang (1978) for coffee products. Binary saturated salt solutions were used to vary water activity (a_w) from 0.1 to 0.9. Laboratory grade and at least 99.5% pure LiCl, $KC_2H_3O_2$, K_2CO_3, $MgCl_2$, KI, NaCl, KCl, and K_2SO_4 were used (Greenspan, 1996; Hutchinson & Otten, 1984). Saturated aqueous salt slurries were prepared and placed in separate desiccators. To determine the sorption data, onion powder samples (about 2 g) were accurately weighed into Petri dishes and left above the saturated salt solutions. Samples were weighed every 2 days until a weight change of $< \pm 0.001$ g was recorded on two consecutive weighings, when the sample was assumed to be at equilibrium. During equilibration, samples were kept at a constant temperature of 20±0.1 °C. Equilibration moisture of each sample was determined by the vacuum oven method (AOAC, 1990). The physical appearance of the samples, with respect to colour, and flowability, was also observed. All determinations were performed in duplicate. The moisture sorption isotherms were transformed using the Brunauer Emmett Teller (BET) equation (Iglesias & Chirife, 1976), and monolayer value "M_0" was calculated from the BET equation,

$$\frac{a_w}{(1\text{-}a_w)M} = \frac{1}{M_oC}$$

where M = Moisture content of onion powder expressed in g per 100 g solids; M_o = g of water equivalent to monomolecular layer adsorbed per 100 g dry solids; a_w = water activity at moisture M; and C = constant related to heat of adsorption.

3. Results and discussion

The onions, Bangalore small variety had moisture content 82.4%, pyruvic acid 16.9 μmol per g and total soluble solids 11.9° Brix. Pyruvic acid appears enzymatically in onion tissue disintegrated by comminution. Ninety-five per cent of the maximum amount of pyruvic acid is produced within 6 min after the start of comminution (Schwimmer & Weston, 1961). The total amount of pyruvic acid produced appeared to depend on the degree of pungency of onion lot investigated. Onions used in this study produced pyruvic acid, 16.9 μmol per g, and are ranked as strong onions, according to Schwimmer and Weston (1961). They have reported that strong onions produce 15 to 20 μmol of pyruvic acid per g of onion. The initial moisture content of freeze-dried, vacuum shelf-dried and through flow-dried onion powders were 3.25, 3.00 and 2.75% (MFB), respectively. There was very good agreement between duplicate measurements of moisture content with maximum deviation ±0.1% from the mean. Water activities of samples varied from 0.1 to about 0.9. Experiments above 0.9 a_w (using K_2SO_4) had to be discontinued due to mould development. The relationship between equilibrium moisture content, days required to reach equilibrium at various water activities and physical appearance of freeze-dried, vacuum shelf-dried and through flow-dried onion powders is presented in Table 1. Sorption isotherm curves of these samples are shown in Fig. 1. As the initial moisture contents of onion samples were low, absorption, not desorption was dominant. The isotherms had sigmoidal shapes typical for foods. The results in Table 1 show that all the samples required almost the same time for equilibration at any a_w. Moisture content at equilibrium was slightly more in the freeze-dried sample, but there was no marked difference in the appearance any of the three samples. Considering the free-flowing property (texture) and appearance of onion powders, the appropriate a_w for storage appeared to be below 0.43. Caking started in

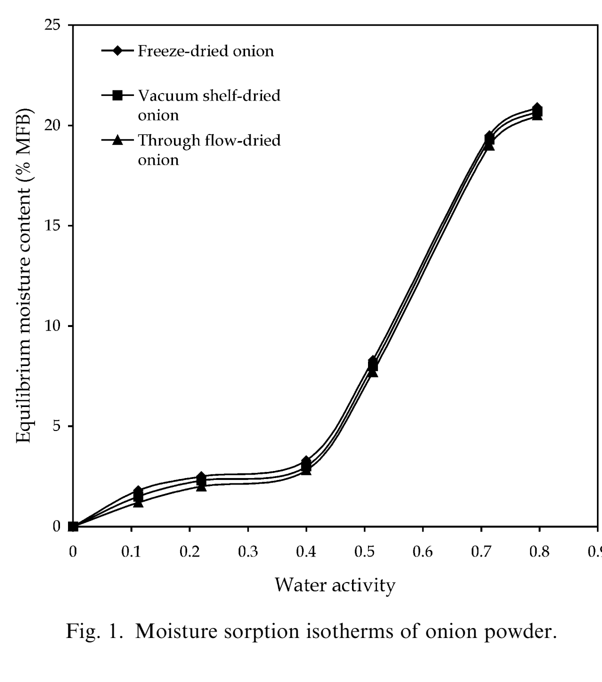

Fig. 1. Moisture sorption isotherms of onion powder.

Table 1
Relation of equilibrium moisture, time required to reach equilibrium, and appearance of onion powder exposed to various water activity at 20±1 °C

Water activity	Sample[a]	Days required for equilibration	Equilibrium moisture (%) MFB[e]	Remarks
0.91	F[b]	–	–	Mouldy after 20 days; flowability reduced after second day.
	V[c]	–	–	
	T[d]	–	–	
0.85	F	35	20.90	Flowability reduced after fourth day; caking was in an advanced stage after 20 days and colour slightly yellowish and dull.
	V	35	20.70	
	T	35	20.50	
0.755	F	30	19.50	Flowability affected after third day; caking in advanced stage; colour creamish and dull.
	V	30	19.25	
	T	30	19.00	
0.69	F	26	16.00	Free-flowing property markedly reduced; appearance good.
	V	26	15.50	
	T	26	15.00	
0.52	F	21	8.25	Free-flowing property markedly reduced; appearance good.
	V	21	8.00	
	T	21	7.75	
0.43	F	12	3.25	Free-flowing; appearance good.
	V	12	3.00	
	T	12	2.75	
0.33	F	14	3.15	Free-flowing; appearance excellent.
	V	14	2.90	
	T	14	2.50	
0.23	F	18	2.50	Free-flowing; appearance excellent.
	V	18	2.25	
	T	18	2.00	

[a] Initial moisture content (%, MFB).
[b] Freeze-dried 3.25.
[c] Vacuum shelf-dried 3.00.
[d] Through flow-dried 2.75.
[e] MFB = moisture free basis.

all three onion powder samples above 0.43 a_w. The time required to reach equilibrium for the three onion powders was found to decrease with a decrease in a_w, and then increase at low values of a_w. This is in accordance with the results of Tsami, Marinos-Kouris, and Maroulis (1990) on dehydrated tropical fruits. The difference, however, lies in the fact that, to reach equilibrium, the fruits required more time in lower ranges of a_w than in the higher ranges of a_w. This difference in moisture sorption pattern may be attributed to the difference in the chemical composition of fruits (water-soluble crystalline components, e.g. sugars or salts and pectins) compared with onion (Tsami et al., 1990).

The isotherm curves (Fig. 1.) are typically sigmoidal in shape, and indicate that equilibrium moisture increases very slowly with increase in a_w up to 0.43, beyond which there is a steep rise in moisture in all three samples. The moisture sorption isotherms are divided into three parts; region 1 ranged between 0 and 0.12 a_w, region II from 0.12 to 0.43 a_w and region III above 0.43 a_w (Labuza, 1984; Tsami et al., 1990). The very pronounced sigmoided shape of the first part of the isotherms indicated that monolayer water was tightly bound to ionic groups such as anion and carboxyl groups (Labuza, 1984; Tsami et al., 1990) at lower levels. In this region, the absence of water molecules, that could hydrate trace metals, and peroxide radicals, increased the susceptibility to oxidative rancidity (Labuza, 1984; Tsami et al., 1990). In region II, there was multimolecular moisture, the fraction being less firmly bound than region 1. In this region, water molecules were predominantly held by covalent bonds, and water was hydrogen-bonded to hydroxyl and amino groups, and was considered as chemisorbed or intermediate state (Labuza, 1984; Tsami et al., 1990). In region III, water had a dominant influence on onion powder stability, and existed as a free molecule and its vapour pressure was influenced by capillary forces and dissolution of soluble constituents, resulting in accelerated undesirable enzyme reactions and microbial growth (Labuza, 1984; Tsami et al., 1990) A comparison of the initial moisture content with the final equilibrium moisture content (EMC) gave a measure of the capacity of that sample, to adsorb or desorb moisture at different water activities. In region I, values of EMC of onion powders were lower than the initial moisture contents, signifying that they lost moisture. According to the BET theory, the monolayer moisture content is considered as that corresponding to the amount adsorbed at specific sites. The monolayer values "M_0" were 2.09, 1.96 and 1.94 for freeze-dried, vacuum shelf-dried, and through flow-dried onion powders, respectively. The critical moisture levels were 8.25, 8.00 and 7.75%, for freeze-dried, vacuum shelf-dried and through flow-dried onion powders, respectively. This critical moisture level is in fact, the level at which onion powder keeps very well, on storage for a longer period of time.

It can be concluded from this study that onion powder belongs to a class of food powders that is highly hygroscopic by nature. The results of this study help in determination of package systems that maximize product protection. Moisture-sorption data give useful guidance for processing and packaging of dehydrated foods. In most cases, the monomolecular layer moisture content is a good first target in the dehydration process when specific stability data are lacking. Also, the compatibilities of food items, which are to be packaged together, can be determined with good reliability.

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