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Rehydration and sorption properties of osmotically pretreated freeze-dried strawberries

Ciurzyńska Agnieszka *, Lenart Andrzej

Faculty of Food Sciences, Department of Food Engineering and Process Management, Warsaw University of Life Sciences, SGGW, Warsaw, Poland

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ABSTRACT

The aim of this work was to investigate the influence of osmotic dehydration and type of osmotic solution on selected physical properties of freeze-dried strawberries. Frozen Senga Sengana strawberries were dehydrated in osmotic solution with water activity of about 0.9 (sucrose and glucose solutions and starch syrup). Osmotically dehydrated fruits were frozen and freeze-dried at heating shelf temperature of 30 °C for 24 h.

Rehydration, sorption isotherms and adsorption rate were determined for the freeze-dried strawberries. A decrease in rehydration capacity and adsorption rate was observed in the case of freeze-dried strawberries that were osmotically dehydrated in sucrose and glucose solution. Osmotic dehydration in glucose solution resulted in flatter sorption isotherms than osmotic dehydration in sucrose and starch syrup solution.

1. Introduction

Strawberries are very sensitive to chemical and microbial deterioration during post-harvest storage and handling, therefore, they have a rather limited shelf life in a fresh form (Duxbury, 1992; Parakash et al., 2004). Strawberries can be consumed fresh or in many other forms (juice, jam, jelly, dried and rehydrated with yogurt and bakery products) (El-Beltagy et al., 2007). Freezing the fruit improves its availability, but despite increased cost, the product quality is poor (Agnelli and Mascheroni, 2002).

In recent years, a variety of drying methods have been tried and much attention has focused on the quality of the products obtained by these methods (Jena and Das, 2005; Matuska et al., 2006). Some studies have been carried out into the production of conventionally air dried berry fruits such as strawberries (Alvarez et al., 1995), blueberries (Lim et al., 1995) or mulberries (Maskan and Gögüs, 1998) which leads to elaborate freeze-drying technology (Tsami and Katsioti, 2000).

Thus, there is a need to modify the freeze-drying method so as to limit its adverse influence, especially on fragile and delicate structures. One possible solution is to apply osmotic dehydration, which involves the immersion of fruit in osmotic solution resulting in the removal of water from tissue, and replacing it with soluble solids (Montserrat and Wet, 2003).

Investigations made in recent years have proved that application of osmotic dehydration to fruit and vegetable pre-treatment yields very good results in decreasing water content in the products, and significantly increases dry mater content (Kowalska and Lenart, 2001). But it has to be noted that because there is a simultaneous influx of osmotic solution into the plant tissue as water is removed, the process may influence nutritional and organoleptic qualities of the tissue (Bonazzi et al., 1996). Accordingly, the osmotic treatment has been used mainly as pre-treatment to some conventional processes such as freezing, vacuum drying, and air drying, in order to improve final quality of products, reduce energy costs, or even to develop new products (Sereno and Hubiner, 2001).

Osmotic dehydration introduces changes in chemical composition. Prothon (2003) observed that it caused a decrease in water absorption capacity during rehydration of vacuum-dried apples. This fact might be related to smaller porosity of the material resulting from saturation of intercellular space and cell walls by sugar. However, Lewicki et al. (1998) found that immersing dehydrated onion in starch syrup resulted in better rehydration capacity. So, it appears that osmotic dehydration conditions before drying are of great consequence for rehydration and water vapour sorption.

The aim of this study was to investigate influence of osmotic dehydration and type of osmotic solution on the chosen physical properties of freeze-dried strawberries. Various conditions of osmotic dehydration were taken into account. An attempt was made to define pre-treatment conditions before freeze-drying of strawberries which could affect rehydration and water vapour sorption of dried fruit.

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* Corresponding author. Tel.: +48 22 59 37 577; fax: +48 22 59 37 576.
E-mail address: agnieszka_ciurzynska@sggw.pl (C. Agnieszka).

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2. Materials and methods

The objectives of analysis was strawberries of Senga Sengana variety, frozen, about 25–30 mm in diameter, with previously removed leaf stalks. They had been stored in plastic pouches of 500 g each at the temperature of −18 °C for 3 months. The frozen strawberries were then osmotically dehydrated in various sugar solutions of water activity equal to 0.9 and different mass weight (MW) [sucrose: 61.5 g/100 g solution, glucose: 49.2 g/100 g solution, starch syrup (glucose equivalent DE 30–35): 67.2 g/100 g solution] in a water bath (ELPAN-357) at the temperature of 30 °C for 3 h under atmospheric pressure. The ratio of material to solution was 1:4 w/w. In the beginning of the osmotic dehydration process water activity of the osmotic solution equal to 0.9 ensures the same driving force in mass exchange. Additionally, the whole system was being shaken with the frequency of 100 Hz and the amplitude of 10 Hz. After the specified period of time, the strawberries were separated from the osmotic solution in a sieve, and rinsed twice in water. During the osmotic dehydration of strawberries, the temperature in the centre of the fruit changed from −10 to 26.5 °C. The measurement was conducted using a thermocouple which was stuck in the centre of the examined fruit (Kowalska and Lenart, 2001; Piotrowski et al., 2004; Matuska et al., 2006; Kowalska et al., 2008).

Next, the osmotically dehydrated strawberries were frozen in a National Lab GmbH (ProfiMaster Personal Freezers PMU series) freezer at the temperature of −70 °C for 2 h. Both osmotically dehydrated and unprocessed frozen strawberries were then dried for 24 h in an ALPHA1-4 LDC-1m freeze-dryer (Christ, Germany) using contact heating under the pressure of 63 Pa, safety pressure 103 Pa, the dryer shelves temperature being 30 °C. During this process of drying, the fruit temperature was being monitored by a thermocouple which indicated that the temperature inside osmotically dehydrated strawberries had risen from −30 to 25 °C. Subsequently, the fruit were put into jars and stored in a dark place at the temperature of 25 ± 3 °C until the time of the planned examination (1–2 months).

The degree of rehydration was estimated on the basis of freeze-dried fruit mass increase during a specified time of immersion in water. The measurement was carried out at room temperature, and the whole procedure was repeated five times (Witrowa-Rajchert and Lewicki, 2006). For this purpose, a whole strawberry (about 1 g in weight) previously weighed on an analytical scales with the accuracy of ±0.001 g was submerged in 100 ml of distilled water contained in each of the four beakers. After the periods of 5, 30, 60, and 120 min, the fruit were consecutively drained, weighed, and their dry matter content was determined (Lenart, 1996).

To establish the isotherms of water vapour sorption (Kowalska and Lenart, 2000), weighed whole strawberries (about 1 g each) had been put in seven chambers filled with salt solution with water activity from 0.113 to 0.903 for 1 month. After that time, samples were weighed again and water activity of the strawberries was determined.

The measurement of water vapour sorption kinetics (Kowalska and Lenart, 2000) was conducted in four repetitions for each type of strawberry using a stand which ensured continuous measurement of mass increase in conditions of constant temperature and relative humidity. Saturated $NaNO_2$ solution was used to obtain constant water activity of environment (0.648). The measurement was carried out at the temperature of 25 ± 1 °C for 20 h. The investigated samples consisted of whole dried strawberries, and their mass increase was registered by means of the “measurement for DOS” computer software.

An exponential equation (Kowalska et al., 2006) was used for mathematical interpretation of the obtained results:

$$u = a + b * \left(1 - \exp^{(-c*\tau)}\right) \tag{1}$$

where u – water content [g H_2O/g d.m.], a, b, c – constant parameters of equation, τ – time [h].

Changes in water content (u) in time (τ) during osmotic dehydration and rehydration of freeze-dried strawberries and water vapour sorption rate were determined. Correlation coefficient R^2; mean relative error MRE (Jamali et al., 2006); error of water content estimation SEE (Jamali et al., 2006); relative squares sum RSS (Pagano and Mascheroni, 2005); and root mean square RMS (Lewicki, 2000) were also computed using the following equations:

$$u = \frac{(1-s)}{s} \tag{2}$$

$$\mathrm{MRE} = \frac{100}{n} * \sum \left| \frac{u_e - u_p}{u_e} \right| \tag{3}$$

$$\mathrm{SEE} = \sqrt{\sum (u_e - u_p)^2} \tag{4}$$

$$\mathrm{RSS} = \sum (u_e - u_p)^2 \tag{5}$$

$$\mathrm{RMS} = \sqrt{\frac{\sum \left(\frac{u_e - u_p}{u_p}\right)^2}{n}} * 100\% \tag{6}$$

where s – dry matter content (g d.m./g), n – number of observations, e – experimental water content, p – predicted water content.

For osmotically dehydrated strawberries, solid gain (SG) was calculated from the equation (Kowalska et al., 2008):

$$\mathrm{SG} = \frac{s_f * m_f - s_i * m_i}{s_i * m_i} \tag{7}$$

where m – sample mass (g), i – initial, f – final.

In the ensuing statistical analysis Statgrafics Plus v. 3.0. (Microsoft), Excel 2000 (Microsoft), Table Curve 2D v. 3 (Jadel) computer software was used. For the obtained averaged results, corresponding standard deviations (SD) were calculated. Statistical comparison for kinetic curves was performed with the use of Statistica 5.0 (StatSoft) software package. In the course of analysis, Fisher's F-test for verification of the hypothesis of equality of means for analysed coefficients in the measured samples was used, and Pearson correlation coefficient was computed. The least significant difference (LSD) between mean values was calculated for analysed technological coefficients considering pairs of investigated samples, in relation to the applied variable using F-test (multiple range test). For the purpose of analyses, significance level of 0.05 was assumed.

3. Results and discussion

3.1. Influence of osmotic dehydration on rehydration properties of freeze-dried strawberries

As a result of the analysis, statistically significant influence of osmotic dehydration (IA-IC) on rehydration of freeze-dried strawberries in comparison to freeze-dried strawberries without osmotic dehydration (I) was discovered (Fig. 1). Freeze-dried fruit after previous osmotic pre-treatment were characterised by lower water contents after 120 min of rehydration than fruit not subjected to osmotic dehydration. It was also noted that osmotic dehydration in starch syrup (IC) caused a significant difference in rehydration in relation to the analogical process in conducted sucrose (IA) and glucose (IB) solution. Between the two latter solutions being no statistically significant difference in this respect (Fig. 1).