Journal of Food Engineering 134 (2014) 37–44

Contents lists available at ScienceDirect

Journal of Food Engineering

journal homepage: www.elsevier.com/locate/jfoodeng

Effect of calcium on the osmotic dehydration kinetics and quality of pineapple

Keila S. Silva [a,b,*], Milena A. Fernandes [b], Maria A. Mauro [b]

[a] UNORP – Northern Paulista University Center, Rua Ipiranga 3460, 15020-040 São José do Rio Preto, SP, Brazil
[b] Department of Food Engineering and Technology, Institute of Biosciences, Language and Physical Sciences (IBILCE), UNESP – São Paulo State University, Rua Cristóvão Colombo 2265, 15054-000 São José do Rio Preto, SP, Brazil

ARTICLE INFO

Article history:
Received 28 August 2013
Received in revised form 17 February 2014
Accepted 22 February 2014
Available online 4 March 2014

Keywords:
Diffusion coefficients
Impregnation
Calcium
Pineapple
Osmotic dehydration

ABSTRACT

The effects of the sucrose and calcium lactate concentrations on the osmotic dehydration kinetics of pineapple, and the diffusivity of each component were investigated. The color, water activity, texture and fruit composition were also evaluated. Osmotic dehydration was carried out using 40% and 50% sucrose solutions with added 0%, 2% or 4% calcium lactate for 1, 2, 4 and 6 h of processing time. In general, the gain in calcium was greater in samples submitted to solutions with higher sucrose and calcium lactate concentrations. The greatest calcium contents (≈90 mg/100 g) were reached after 6 h of impregnation in both 40% and 50% sucrose solutions containing 4% calcium lactate. The addition of calcium to the osmotic solution reduced the water content of the product and solute incorporation rate, inhibiting sucrose impregnation and increasing process efficiency. The addition of 4% calcium lactate to the solution increased all diffusivities in comparison to the addition of 2% but not in relation to treatments with no added calcium. Calcium impregnation did not influence the color of the product or the value for stress at rupture, as compared to raw pineapple. The diffusion coefficients presented in this work permitted the selection of the appropriate sucrose and calcium concentrations and the calculation of the processing time to give the desired product composition.

1. Introduction

Pineapple is a popular fruit from tropical and subtropical regions, available throughout the year and widely consumed around the world. Brazil is the second largest producer of pineapples in the world (FAOSTAT, 2011). Pineapple has a short shelf life, which increases postharvest losses. The industries produce different pineapple products (such as the minimally processed fruit and chips) aiming to facilitate consumption of the fruit and reduce losses. During the process, the nutritional quality of pineapple can fall, and for this reason alternative methods that minimize undesirable alterations in the product must be studied. Osmotic dehydration is a treatment that can be used to enhance the nutritional characteristics and add value to the final products.

Osmotic dehydration (OD) is a water removal process that can be employed to obtain minimally processed food with a longer shelf life and improved nutritional value. As a pretreatment to drying, OD can reduce the moisture content of a plant by approximately 50%, can also reduce aroma losses and enzymatic browning and increase sensory acceptance and the retention of nutrients (Ponting et al., 1996; Shi et al., 1999; Torreggiani and Bertolo, 2001; Pan et al., 2003; Lombard et al., 2008). The osmotic treatment also allows for an increase in the nutritional value of fruits and vegetables due to the impregnation of minerals and vitamins into its porous structure (Fito et al., 2001).

Osmotic dehydration reduces the moisture content of fruits and vegetables by immersing them in aqueous concentrated solutions containing one or more solutes (Sereno et al., 2001; Garcia et al., 2007). Hypertonic solutions provide a high osmotic pressure that promotes the diffusion of water from the vegetable tissue into the solution and the diffusion of solutes from the osmotic solution into the tissue (Rastogi et al., 2002). This mass transfer depends on some factors such as the geometry of the product, temperature, and the concentration and agitation of the solution.

The characteristics of the osmotic agent used, such as its molecular weight and ionic behavior, strongly affect dehydration, both water loss and solute gain. Moreover, the sensory and nutritive properties of the final product can be affected by the solute used

* Corresponding author at: Department of Food Engineering and Technology, Institute of Biosciences, Language and Physical Sciences (IBILCE), UNESP – São Paulo State University, Rua Cristóvão Colombo 2265, 15054-000 São José do Rio Preto, SP, Brazil. Tel.: +55 17 98139 5278.
E-mail address: keilasouzas@yahoo.com.br (K.S. Silva).

http://dx.doi.org/10.1016/j.jfoodeng.2014.02.020
0260-8774/

in the osmotic process (Ramallo et al., 2004; Telis et al., 2004; Ferrari et al., 2010). Saputra (2001) verified that sucrose provides a greater water loss and smaller solute gain when compared to glucose, in the case of pineapple samples submitted to osmotic dehydration. Cortellino et al. (2011) observed that the osmotic pretreatment in a sucrose solution protected the color of pineapple rings during drying.

The addition of calcium salts to osmotic solutions has been used to reduce the damage caused to the structure of the cell wall due to dehydration (Mastrantonio et al., 2005; Pereira et al., 2006; Heredia et al., 2007 and Ferrari et al., 2010). However, the use of these salts in osmotic solutions can also increase the rate of water loss, reduce the water activity and increase the calcium content of the vegetables and fruits, resulting in fortified products (Heng et al., 1990; Rodrigues et al., 2003; Pereira et al., 2006; Heredia et al., 2007 and Silva et al., 2013). The food industry has been encouraged to fortify its food with calcium to increase consumer calcium intake, preventing some diseases without the use of supplementation (Cerklewski, 2005; Martín-Diana et al., 2007).

Anino et al. (2006), exploring the possibility of obtaining calcium enriched products, analyzed the tissue impregnation capacity of minimally processed apples in a solution containing 10.9% (w/w) glucose, 5266 ppm of calcium salt (a blend of calcium lactate and calcium gluconate), 1500 ppm potassium sorbate, and citric acid to correct of the pH to 3.5, with and without the application of vacuum. The process carried out without the application of vacuum was more efficient. The amount of calcium incorporated into the apple samples were 1300 ppm after 6 h and 3100 ppm after 22 h of processing without the application of vacuum. In the vacuum process, the impregnation ranged between 1150 and 2050 ppm.

Several trials on osmotic dehydration with the addition of calcium salts have been published lately, aiming to reduce the damage caused to the structure of the cell wall (Mastrantonio et al., 2005; Pereira et al., 2006; Heredia et al., 2007; Ferrari et al., 2010). However, few have considered the kinetics and diffusivity of each component in the ternary solution (Antonio et al., 2008; Monnerat et al., 2010) or the calcium diffusivity (Barrera et al., 2009, 2004) in the vegetable tissue. Knowledge of the kinetics and diffusivity of the components helps to understand the internal mass transfer that occurs during osmotic dehydration and to model the mechanism of the process (Singh et al., 2007).

This study aims to investigate: – the effects of the sucrose and calcium lactate concentrations on the osmotic dehydration kinetics of pineapple, and the diffusivity of each component; – the influence of the sugar, calcium salt and time of osmotic dehydration on the color, water activity, texture and calcium content of the pineapple.

2. Materials and methods

2.1. Materials

Pineapples (*Ananás comosus* (L.) *Merril*) with a commercial degree of ripeness, soluble solids content between 13 and 14 °Brix, weighing approximately 1.2 kg, were immersed in a solution of 0.1% sodium hypochlorite for 5 min, washed in running water, dried at room temperature and manually peeled. The tops and tails were discarded to reduce tissue variability. The pieces were sliced (1 ± 0.1 cm thick) and the slices cut into a truncated cone format with the aid of a metal mold. The water, sucrose and calcium contents of the fresh pineapples used in the experiments are presented in Table 1.

The osmotic solutions were prepared using commercial sucrose (amorphous refined sugar) purchased at a local market; food grade calcium lactate pentahydrate in powder form obtained from PURAC® Synthesis – Brazil, and distilled water.

2.2. Procedures

2.2.1. Osmotic dehydration kinetics and diffusion coefficients

The pineapple slices were arranged in four nylon mesh baskets, with approximately 350 g of samples in each basket. The baskets were immersed in 20 kg of aqueous solution, continuously stirred using a 1.6 kw mechanical stirrer (Marconi, model MA-261 – Brazil) with a 10 cm diameter propeller and rotation at 1850 rpm. The temperature of the solution was maintained at 27 °C and the syrup-to-fruit ratio was approximately 1:14 (1.4 kg of sample/20 kg of solution).

The aqueous solution concentrations studied were 40% and 50% sucrose (*SUC*), with and without the addition of 2 or 4% calcium lactate (*LAC*), each process being carried out for 1, 2, 4 and 6 h. At the end of each processing time, one basket was removed from the osmotic bath and the samples immersed in distilled water at room temperature for 10 s to remove the osmotic solution from the surface. They were then blotted with absorbing paper and weighed. The total solids, total and reducing sugars and calcium contents were analyzed before and after each treatment. The influence of the time and addition of sucrose and calcium lactate to the osmotic solution, on the mass transfer were compared. The equilibrium concentration of the water, sucrose and calcium was determined by soaking thin fruit slices (3 mm thickness) in a flask containing approximately 600 g osmotic solution. The solutions were maintained at 27 °C with orbital agitation at 165 rpm and a syrup-to-fruit ratio of approximately 1:10. After 48 h, the flasks were removed, and the pieces drained, dipped in distilled water for 10 s and blotted with absorbent material. The samples were then prepared for the analysis of their water, sucrose and calcium contents.

2.3. Analytical methods

The water contents of the fresh and osmotically dehydrated samples were gravimetrically determined in triplicate by drying the samples in a vacuum oven at 60 °C and 10 kPa to constant weight. The total and reducing sugar contents of the fresh and osmotically treated samples were determined in triplicate by the oxidation–reduction titration method (AOAC, 1970). The calcium concentrations of the fresh and dehydrated samples were determined in duplicate using flame atomic absorption spectrometer (SpectrAA 50B of Varian – Mulgrave, Australia), according to adapted AOAC (1995) methodology. The water activity of the samples was measured in triplicate at 25 °C in a hygrometer (AW SPRINT; NOVASINA, Switzerland). The color of the fresh and osmotically dehydrated fruits was evaluated (4 replicates) using a Colorflex spectrophotometer (HunterLab, USA) with version 4.10 of the Universal software. The response was expressed in the form of the parameters L^* (lightness: 100 for white and 0 for black) and Chroma (C^*):

$$C^* = \sqrt{(a^*)^2 + (b^*)^2} \quad (1)$$

where a^* (green–red) and b^* (yellow–blue) are the color parameters.

The texture of the fresh and osmotically dehydrated samples was determined by evaluating (10 replicates) stress at rupture in a Universal texturometer (TA-XT2i Texture Analyser, Stable Micro System, Surrey, UK.). The method used was to measure the force in compression at the moment of rupture. This uniaxial compression test was carried out at a compression speed of 5 mm/s and 60% sample deformation. The stress at failure was determined from the peak of the stress–strain curve (Pereira et al., 2006).