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Compositional and physicochemical changes associated to successive osmodehydration cycles of pineapple (*Ananas comosus*)

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Abstract

As a technique for obtaining minimally processed fruits, osmotic dehydration (OD) is adequate, and does posses advantages over other drying techniques, yet it seems that some hydrosoluble components may escape into the osmotic solution (OS) during the process. On the other hand, the re-use of the OS in successive OD operations can be a good way of making the process economical and environmentally friendly. In this work, 15 successive cycles of pineapple dehydration were programmed. OD was carried out for 2 h at 30 °C with an OS:fruit rate of 20:1, using a 55 °Brix sucrose solution. In each OD cycle, the fruit was renewed but the OS was re-used without any re-concentration treatment. In each cycle, soluble solids (°Brix), water content (x_w), water activity (a_w), pH, citric acid (CA), majority minerals (Ca, Mg, K, P and Na) and pectin content were analysed in the pineapple slices and in the OS. Electrical conductivity (EC) and viscosity (μ) of the OS were also analysed. The results obtained allow us to confirm a loss of CA, pectin and studied minerals that ranged between 21 and 59 mg/100 mg of the component present in the fresh fruit. The flow of these components to the OS may be predicted from EC and μ measurements of the OS.

Keywords: Osmotic solution; Fruit; Soluble solids; Citric acid; Minerals; Pectin; Electrical conductivity; Viscosity

1. Introduction

There is an ever-increasing consumer demand for products with a relatively long life-span, which preserve the characteristics of fresh products. In the case of fruit, to obtain a fresh-like product implies certain operations such as peeling, cutting and packaging in a syrup or often, partial dehydration of the product. In this case, osmotic dehydration has been the most effective method of dehydration (Talens, Hartong, Martínez-Navarrete, Chiralt, & Fito, 2000) with some advantages over other methods of drying, but it also brings some problems.

Osmotic dehydration consists of the immersion of a solid food in watery solutions with a high soluble solid concentration. This technique causes a two-way mass transfer in crosscurrent: water and also some natural soluble substances flow out of the fruit into the OS, and in the opposite direction, soluble solids may be transferred from the solution to the fruit (Barat, Andrés, & Fito, 1998). Due to the kinetic of the OD operation it may be used to obtain products of reduced but still relatively high moisture content, classified as intermediate moisture products, but microbiologically stable due to reduced water activity (García-Martínez, Martínez-Monzó, Camacho, & Martínez-Navarrete, 2002).

During OD, the fruits are not submitted to high temperatures, thus minimising changes in sensory attributes, such as colour, aroma flavour and texture (Fito, Andrés, Pastor, & Chiralt, 1995; Heng, Guilbert, & Cup, 1990; Raoult-Wack, 1994). Nevertheless, a loss of acids, vitamins, polysaccharides and minerals, which flow from the fruit to the osmotic solution, has been observed (Córdoba, García-Martínez, Martínez-Navarrete, Camacho, & Martínez-Monzó, 2003; García-Martínez et al., 2002; Peiró, Dias, Camacho, & Martínez-Navarrete, 2006; Uzuegbu &

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Ukeka, 1987). Furthermore, as opposed to other traditional drying treatments, OD does not affect the food structure because water elimination does not involve phase changes (Forni et al., 1987; Giangiacomo, Torreggiani, Erba, & Messina, 1994; Pinnavaia, Dalla-Rosa, & Lerici, 1988).

However, one important factor related to this technique is that the osmotic solution used in the fruit OD process, commonly a sugar solution, is normally not re-used and can be considered as industrial waste, which not only greatly increases the cost of the osmodehydrated products, but also, if the sucrose syrup is discarded, once used, may result in loss of valuable natural substances such as vitamins, minerals, etc. Therefore, the possibility of recycling osmotic solutions or using them it in order to formulate some foods is very important for making the process economically and environmentally friendly (Shukla, 2001; Valdez-Fragoso, Welti-Chanes, & Giroux, 1998). Reusing OS in more OD cycles is conditioned by compositional solution changes, as a progressive OS dilution after each cycle could slow down the mass transfer rate. When using in food formulations, in which the nutritional components lost by osmodehydrated fruits should be present, not only compositional but also physical changes such as in viscosity, electrical conductivity, etc., which occur, during fruit OD, have to be taken into account.

On this basis, the objective of this paper was to study some compositional (water, soluble solids, citric acid, majority minerals and pectin) and physicochemical (water activity, electrical conductivity and viscosity) changes associated to osmodehydration of pineapple, both in the fruit and in the sucrose solution used as the osmotic agent. These changes were studied when OS was re-used for 15 successive pineapple OD cycles, so that the fruit was renewed for each cycle, but the OS was re-used without any previous treatment.

2. Materials and methods

2.1. Raw matter

Golden sweet pineapples (*Ananas comosus*) from The Ivory Coast, purchased in local markets in Valencia (Spain), were stored under refrigeration conditions (8 °C) till the moment of use (maximum 24 h). Fruit of a similar ripeness (between 11 and 13 °Brix), of a good, uniform visual quality were selected. They were peeled and cylindrically sliced with a borer (8.5 cm external diameter, 2.6 cm internal diameter and 1 cm thickness).

55 °Brix sucrose solution was used as osmotic agent, prepared from food grade commercial sugar mixed with gently heated (30 °C) distilled water until it was completely dissolved.

2.2. Osmotic dehydration process

Pineapple slices were osmodehydrated for 2 h in a plastic tank filled with 55 °Brix sucrose syrup and placed in a temperature-controlled water bath (30 °C). The syrup was continuously stirred with a Heidolph RZR2102 stirrer at 200 rpm. A plastic screen was placed over the basket to keep the slices totally immersed in the solution and separate from the stirrer. Dehydration time was selected in order to obtain pineapple with 75% moisture content, based on the results obtained in previous osmotic dehydration kinetic studies (Valero, 2003). The mass ratio OS:fruit was 20:1 and 15 dehydration uses (cycles), were considered. The osmotic solution used was not re-concentrated and was the same for all the cycles, but the fruit was renewed for each cycle after the 2 h of dehydration.

2.3. Analysis

Chemical and physical analyses were performed in the sucrose syrup after 0, 1, 3, 5, 7, 9, 12 and 15 cycles. OS was characterised as to the following physicochemical parameters: soluble solids (°Brix) at 20 °C (ATAGO model NAR-3T refractometer, Japan), water activity (a_w; Decagon model CX-2 dew point hygrometer), pH (Crison micro pH 2001 pH-meter), electrical conductivity at 20 °C (EC; Crison 522 conductimeter) and total acidity calculated as citric acid (CA) by a titration with NaOH. All analyses were performed in triplicate.

Besides viscosity (μ; Physica Rheolab MC1 rheometer at 25 °C, shear rate ($\dot{\gamma}$) sweep from 0 to 150 s^{-1} in 90 s), the pectin content and majority mineral content of OS were also determined.

Galacturonic acid residues are the fundamental units of pectin chains and quantifying this acid was a primary method used to determine the amounts of pectin material present in a sample (Kitner & Van Buren, 1982). To this end, samples were ethanol-extracted by centrifugation and the precipitate containing the alcohol-insoluble solids was extracted with sulphuric acid and distilled water (Ahmed & Labavitch, 1977). Determination of pectin content of the extract was carried out by the *m*-hydroxydiphenyl method (Kitner & Van Buren, 1982) reading the absorbance of the samples at 520 nm (Cecil 1020 spectrophotometer).

Minerals were analysed according to the method described by De la Fuente, Montes, Guerrero, and Juárez (2003), consisting of a mineralisation of samples by dry ashing in a muffle furnace and a posterior dilution of the ashes with concentrated hydrochloric acid and distilled water. Calcium and magnesium were determined by atomic absorption spectrometry using a multi-element (Ca–Mg–Zn) hollow-cathode lamp. Potassium and sodium were analysed by atomic emission spectrometry. A 3110 atomic absorption spectrometer (Perkin-Elmer) in an air–acetylene flame was used for the analysis. Phosphorus was measured using a UV–vis spectrophotometer, Cecil 1020.

Both fresh and osmodehydrated pineapple slices were also analysed in triplicate, the latter after each OD cycle, as to water content (x_w), °Brix, a_w, pH, citric acid, pectin content and the same mineral content described for OS.