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Survey of quality indicators in commercial dehydrated fruits

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ABSTRACT

Physical and chemical quality parameters (dry matter, a_w, protein, carbohydrates, vitamin C, 2-furoylmethyl amino acids, rehydration ratio and leaching loss) have been determined in 30 commercial dehydrated fruits (strawberry, blueberry, raspberry, cranberry, cherry, apple, grapefruit, mango, kiwifruit, pineapple, melon, coconut, banana and papaya). For comparison purposes, strawberry samples processed in the laboratory by freeze-drying and by convective drying were used as control samples. Overall quality of dehydrated fruits seemed to be greatly dependent on processing conditions and, in a cluster analysis, samples which were presumably subjected to osmotic dehydration were separated from the rest of fruits. These samples presented the lowest concentration of vitamin C and the highest evolution of Maillard reaction, as evidenced by its high concentration of 2-furoylmethyl amino acids. This is the first study on the usefulness of this combination of chemical and physical indicators to assess the overall quality of commercial dehydrated fruits.

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1. Introduction

Fruits and vegetables of premium quality are currently highly appreciated by consumers, not only for their high nutritional value and pleasant organoleptic properties, but also for their content in bioactive compounds (vitamins and antioxidants, among others) directly related to health benefits (Giampieri et al., 2012). Thus, several fruits like kiwifruit, papaya, strawberry, pineapple or grapefruit are highly appreciated for their high content of vitamin C, a major natural antioxidant compound (USDA, 2013).

Although fruits are usually consumed as fresh products, they are seasonal in nature and highly perishable and, therefore, they are frequently processed to obtain longer shelf-life products such as juice, fruit beverage, wine, jam, marmalade, jelly, frozen and dehydrated products, etc. (Rada-Mendoza, Olano, & Villamiel, 2002; Sanz, del Castillo, Corzo, & Olano, 2001). Among them, dehydrated products are gaining considerable attention due to the present life style and, in recent years, the presence of dehydrated fruits in the market has increased considerably. In addition to fulfill direct consumers' demand, large amounts of dehydrated fruit production are addressed for the industrial elaboration of breakfast cereals, bakery, desserts and confectionery products. In 2006, the European Union production of dehydrated fruits amounted to 1700 million euros corresponding to 428 thousand tons and their consumption was valued at 2300 million euros and 871 thousand tons. Italy, the United Kingdom and Spain were the three largest markets (CBI, 2008).

Although different dehydration processes are used by food processing industries, convective drying is the most common due to its simplicity of operation and affordable technology. Freeze-drying (FD), the best method of water removal to obtain final products of the highest quality, is also used in the industry (Asami, Hong, Barret, & Mitchell, 2003; Marques, Prado, & Freire, 2009). However, its high energetic costs make this process only profitable for the dehydration of high-value products (Ratti, 2001).

Another important aspect to be considered in the dehydration of vegetables and fruits is the pre-treatment applied (Agnieszka & Andrzej, 2010a; Gamboa-Santos, Soria, Villamiel, & Montilla, 2013). Osmotic dehydration (OD), in which the food is immersed in solutions of different sugars, is one the most common pre-treatments applied in industry and it provokes water loss and soluble solids exchange (Nahimana, Zhang, Mujumdar, & Ding, 2011). These mass exchange processes might have an effect on the organoleptic properties and/or nutritional value of the dehydrated product, and may lead to final products with very different quality attributes (Lewicki, 2006).

Furthermore, during the whole dehydration process, important changes affecting the quality of the food can also be produced, and their extent depends on the conditions used. Thus, severe heating favours the loss of thermolabile compounds such as vitamin C

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(Frías, Peñas, Ullate, & Vidal-Valverde, 2010; Wojdylo, Figiel, & Oszmianski, 2009). Moreover, this compound together with other soluble solids as sugars, acids, minerals, hydrophilic vitamins, etc. can also be lost by leaching during OD (Azoubel et al., 2009).

Other important change is the Maillard reaction (MR) that can also occur during drying and storage of the final products. This reaction is influenced by factors such as water activity (a_w), temperature, pH and chemical composition of foods. In the first stage of MR, Amadori compounds are formed and their derivatives obtained after acid hydrolysis, the 2-furoylmethyl amino acids (2-FM-AA), have been previously reported as useful markers of the evolution of this reaction in dehydrated fruits and food products derived from fruits (Rada-Mendoza et al., 2002; Sanz et al., 2001). The evaluation of the Amadori compounds provides very valuable information for process control and for nutritional evaluation, as it reveals not only the loss of available essential amino acids as lysine, but also of other amino acids such as arginine, whose content in fruits might be reduced by MR.

Shrinkage and hardening are the most important physical changes taking place during drying of dehydrated fruits. These are due to modification of tissue microstructure and to chemical changes affecting saccharides and proteins and they can negatively affect the rehydration ability of dehydrated fruits (Lewicki, 2006; Sagar & Kumar, 2010).

The aim of the present study was to evaluate different chemical and physical quality indicators (humidity, a_w, protein, carbohydrates, vitamin C, 2-FM-AA, rehydration ratio (RR) and leaching loss (LL)) in 30 commercial dehydrated fruits, in order to determine their nutritional quality and to tentatively identify the kind of processing to which they have been subjected in the industry. For comparative purposes, these parameters were also determined in two additional samples processed in the laboratory by convective drying and by FD. To the best of our knowledge, this is the first study in which MR together with the other chemical and physical indicators have been assessed in this sort of samples.

2. Materials and methods

2.1. Samples

Twelve samples of dehydrated strawberries (*Fragaria x ananassa*), two cranberries (*Vaccinium oxycoccos*), two blueberries (*Vaccinium corymbosum*), one raspberry (*Rubus idaeus*), two cherries (*Prunus avium*), two kiwifruits (*Actinidia chilensis*), two coconut (*Cocos nucifera*), one banana (*Musa sapientum*), one apple (*Pyrus malus*), one grapefruit (*Citrus paradisi*), one mango (*Mangifera indica*), one papaya (*Carica papaya*), one pineapple (*Ananas comusus*) and one melon (*Cucumis melo*) were purchased from local markets in Madrid and Barcelona (Spain) and in Fribourg (Germany). Seven of these samples were labeled as freeze-dried (FD) products and no information on the process was provided for the rest of fruit samples analysed (samples labeled as D). In addition, raw strawberries were laboratory dehydrated using a convective prototype (7 h, 60 °C, 4 m/s air rate) or a freeze-dryer and they were used as control samples. Dehydrated fruits were stored at a refrigeration temperature of 4 °C up to 1 week before analysis.

2.2. Characterisation of samples

The dry matter (DM) content of samples was gravimetrically determined in an oven at 102 °C until constant weight according to the AOAC (1990a). Water activity (a_w) measurement was carried out in an AW Sprint TH-500 instrument (Novasina, Pfäffikon, Switzerland). Protein content was determined using the Kjeldahl method (AOAC, 1990b) and 6.25 as conversion factor.

2.3. Determination of carbohydrates

Carbohydrates were extracted from dehydrated fruits previously ground to powders using a laboratory mill IKA A-10 (IKA Labortechnik, Staufen, Germany). Thirty milligrams of sample were weighted into a polyethylene tube and extracted at room temperature with 2 mL of Milli-Q water under constant stirring for 20 min. Then, 8 mL of absolute ethanol were added, followed by 0.2 mL of an ethanolic solution 10 mg/mL of phenyl-β-D-glucoside (Sigma–Aldrich Chemical, St. Louis, Missouri, USA) used as internal standard. After stirring for 10 min, samples were centrifuged at 9600*g* for 10 min and the supernatant was collected. Precipitates were subjected to a second extraction with 10 mL of 80% ethanol under the same conditions to obtain recovery values close to 100%. Finally, an aliquot (2 mL) of merged supernatants was evaporated under vacuum at 40 °C and derivatised.

Trimethylsilyl oximes (TMSO) of saccharides were prepared according to Sanz, Sanz, and Martínez-Castro (2004). Oximes were obtained by adding 200 μL of a 2.5% solution of hydroxylamine hydrochloride in pyridine and heating the mixture at 70 °C for 30 min. These derivatives were then silylated with hexamethyldisilazane (200 mL) and trifluoroacetic acid (20 mL) at 50 °C for 30 min. Reaction mixtures were centrifuged at 7000*g* for 2 min at room temperature. Supernatants were injected into the GC system or stored at 4 °C prior to analysis.

Analyses were performed on an Agilent Technologies gas chromatograph (Mod 7890A) equipped with a flame ionisation detector (GC-FID). Separation was carried out in a fused silica capillary column HP-5MS (25 m × 0.32 mm × 0.25 μm film thickness; J&W Scientific, Folsom, CA, USA). Nitrogen at a flow rate of 1 mL/min was used as carrier gas. The oven temperature was held at 200 °C for 11 min, raised to 315 °C at a heating rate of 15 °C/min and held for 5 min. Injector and detector temperatures were 280 and 315 °C, respectively. Injections were made in split mode (1:30). Data acquisition and integration were done using Agilent ChemStation Rev. B.03.01 software (Wilmington, DE, USA).

For quantitation, standard solutions of glucose, fructose, *myo*-inositol, sucrose, kestose and mannitol over the expected concentration range in extracts of dehydrated fruits were prepared and analysed in triplicate to calculate the response factor relative to phenyl-β-D-glucoside. All determinations were carried out in duplicate and data were expressed as mean ± standard deviation (SD).

2.4. Analysis of 2-furoylmethyl amino acids (2-FM-AA)

Determination of 2-FM-AA in dehydrated fruits was performed by ion-pair RP-HPLC following the method of Resmini and Pellegrino (1991). Before analysis, samples (250 mg) were hydrolysed with 4 mL of 8 N HCl at 110 °C for 23 h under inert conditions. The hydrolysate was filtered through Whatman No. 40 filter paper and 0.5 mL of filtrate was applied to a previously activated (methanol and water) Sep-Pak C_{18} cartridge (Millipore). 2-FM-AA were eluted with 3 mL of 3 N HCl and 50 μL were injected into the chromatograph. RP-HPLC analysis was carried out in a C_8 column (250 mm × 4.6 mm, 5 μm) (Alltech 2-FM-Lys (furosine)-dedicated, Nicolasville, KY) thermostatised at 37 °C, using a linear binary gradient at a flow rate of 1.2 mL/min. Mobile phase consisted of solvent A, 0.4% acetic acid, and solvent B, 0.3% KCl in phase A. The elution program was as follows: 100% A from 0 to 12 min, 50% A from 20 to 22.5 min, and 100% A from 24.5 to 30 min. Detection was performed using a variable wavelength UV detector set at 280 nm (Beckman System 166, Fullerton, CA, USA). Acquisition

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