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Pretreatments for melon drying implementing ultrasound and vacuum

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ABSTRACT

The aim of this work was to evaluate the use of ultrasound, osmotic dehydration and vacuum as a pretreatment on melon drying and product quality. The pretreatment consisted in four processing conditions, using vacuum and/or ultrasound and a control sample with no application of ultrasound and vacuum. Melon samples were immersed in a liquid medium (distilled water or sucrose solution) and pretreated for 10, 20 and 30 min. The drying process was conducted in a fixed bed dryer at 60 °C and air velocity of 2 m/s. The dried pretreated samples with ultrasound and with a combination of ultrasound and vacuum presented faster drying rates. Evaluation of the final product was performed by means of total carotenoid content, texture, color and sensorial test. Dried melon pretreated using ultrasound and vacuum combined obtained higher total carotenoids content, softer texture and total color difference similar to the untreated dried fruit. Sensory evaluation showed that this pretreated sample had good acceptance and no significant difference from the dried untreated melon. Therefore, the use of ultrasound or a combination of ultrasound and vacuum as a pretreatment could improve the efficiency of melon drying, being an alternative to traditional drying and suitable to an industrial context.

1. Introduction

Melon (*Cucumis melo* L.) is a fruit that has high economic value. In terms of production, it is a widely cultivated crop and, among its varieties, Cantaloupe and Honeydew are commonly grown and are appreciated by consumers (Laur & Tian, 2011; Nuñez-Palenius, Gomez-Lim, Ochoa-Alejo, Grumet, Lester, & Cantliffe, 2008; Boriss, Brunke, & Kreith, 2006).

Fresh melon is perishable and rapidly deteriorates. In order to take advantage of the potential health benefits of melon and add value to the fruit, drying represents one of the possible conservation methods to extend shelf life and potentially increase the use of the fruit. On the other hand, drying can significantly affect the quality of melon products, including color change, reduction in bioactive compounds, and texture.

There have been many advances in drying technology in recent years, including pretreatments, techniques, equipment and quality (Başlar, Kiliçh, & Yalinkiliç, 2015). Pretreatments are used in order to accelerate the drying process, enhance quality and improve the safety of foodstuffs. An example is the use of ultrasound or vacuum by several researchers as a pretreatment technique to increase the mass transfer rate between the sample and its surroundings (Lima et al., 2016; Nowacka, Wiktor, Sledz, Jurek, & Witrowa-Rajchert, 2012). In addition, drying of pretreated fruits has been widely studied, in particular when combined with osmotic dehydration (Ribeiro, Aguiar-Oliveira, & Maldonado, 2016; Silva, Amaral, Duarte, Mata, Silva, Pinheiro et al., 2013; Azoubel El-Aouar, Tonon, Kurozawa, Antonio, Murr et al.., 2009; Fernandes, Rodrigues, Gaspareto, & Oliveira, 2006; among others) and/or ultrasound (Medeiros, Barros, Carvalho, Fraga Neta, Maciel, & Azoubel, 2016; Azoubel, Baima, Amorim, & Oliveira, 2010; Fernandes, Oliveira, & Rodrigues, 2008; among others). Few studies are related to osmotic dehydration and/or ultrasound pretreatments and drying of melon (Rodrigues & Fernandes, 2007a, 2007b; Teles et al., 2006).

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However, the use of vacuum and ultrasound combined as a drying pretreatment has not been reported to melon or any other fruit.

The objective of this work was to evaluate the use of ultrasound and/or vacuum pretreatments on drying efficacy of melon slices and to quantify the quality parameters such as total carotenoid content, color, texture and sensory acceptance of dried melon slices.

2. Material and methods

2.1. Raw material

Cantaloupe melons (*Curcumis melo* var. *cantalupensis* Naud) were obtained from a local market (Recife, PE, Brazil). Melons of similar shapes and sizes were washed, cut into halves, deseeded and peeled. The edible portion (mid-section of mesocarp) was cut into slices (3.0 × 5.0 × 0.5 cm) using cutters designed for this purpose.

2.2. Pretreatment

Four melon processing conditions were used: a) control (no application of ultrasound and vacuum) (0 US + 0 VC); b) Ultrasound (US); c) Vacuum (VC); d) Ultrasound and vacuum combined (USVC). For each of these conditions, processing times of 10, 20 and 30 min were tested.

Two melon slices were placed in 250 mL conical flasks containing distilled water or a sucrose solution containing 50 g sucrose/100 g water. The ratio between the liquid medium and the fruit ratio was 4 g:1 g (Azoubel et al., 2010).

The design of the processing technique was based in Başlar et al. (2015). Melons were treated by ultrasound (US), by vacuum (VC) and by a combination of both simultaneously (USVC). Ultrasonic was transmitted in an ultrasonic bath with a thermostat (Unique, model USC-2850A, Brazil), without mechanical agitation. The ultrasound frequency was 25 kHz and the intensity was 4870 W/m^2. The vacuum was supplied from a vacuum pump (Marconi, model MA-2057, Brazil) with 24 L/min pump speed. The vacuum degree was maintained between 0.02 and 0.03 MPa. Experiments where were performed at 30 °C and the temperature increase was lower than 2 °C after 30 min of processing.

After the time of pretreatment, samples were removed from the conical flaks, washed with distilled water (only for melons immersed in sucrose solution), drained, blotted with absorbent paper to remove excess solution/water and finally weighted on a semi-analytical scale. The pretreatment was evaluated in terms of water loss and solid gain. The moisture content of the samples was determined in an oven (Tecnal, model TE-395, Brazil) at 105 °C for 24 h (AOAC, 1998).

Optimum processing conditions were determined to proceed with drying, in order to maximize water loss and minimize solids gain.

2.3. Drying

Drying was performed with untreated melon and with samples obtained under optimized conditions of pretreatment using a convective dryer (Sulab, Brazil) at 60 °C and constant air velocity of 2.0 m/s. The dryer system was described by Azoubel et al. (2010).

For each experiment, nine melons slices were spread on the drying tray (for sensorial analysis it was twelve slices). During processing, moisture contents of melon samples were determined by removing the tray from the dryer every 15 min. Then, it was rapidly weighted on a digital balance near the dryer and placed back into the equipment. Drying was completed when the dynamic equilibrium between the sample moisture content and drying air humidity was reached, when there was no significant change in the weight of the sample (105 min for the untreated sample and for the sample pretreated in sucrose solution and vacuum for 10 min; 75 min for the sample pretreated in distilled water using ultrasound for 10 min; 90 min for the sample pretreated in distilled water using ultrasound and vacuum).

2.4. Determination of total carotenoids content

The total carotenoid content was quantified based in the methodology of Rodriguez-Amaya (1999a), described in brief by Medeiros et al. (2016). Total carotenoids were expressed as μg per g of DM (dry matter). All analysis was carried out in triplicate.

2.5. Color

The color of dried melon was determined using a colorimeter (Minolta, model CR400, Japan), which was calibrated prior to taking any reading. The colorimeter was based on the CIELab method, where L^* represents the whiteness/brightness, a^* represents the redness/greenness and b^* represents the yellowness/blueness. Total color difference (TCD) was calculated using Eq. (1). The reference value for TCD was the fresh fruit. Five replicates of the measurements were performed.

$$TCD = \sqrt{\left(L^* - L_o^*\right)^2 + \left(a^* - a_o^*\right)^2 + \left(b^* - b_o^*\right)^2} \quad (1)$$

2.6. Texture

Texture property of the fresh and processed samples was measured as puncture force, which was a measure of the hardness (N) of the product surface, using a Brookfield CT3 Texture Analyzer (USA) at room temperature. Penetration tests were conducted with a 12.7 mm flat cylinder probe (TA10). The operational parameters were as follows: trigger force was 5 g, constant speed of 1 mm/s and deformation ratio of 60%. All tests were carried out in triplicate and in each sample, penetration tests were made at three points.

2.7. Sensorial analysis

Melon with and without pretreatments, dried at 60 °C up to a moisture content of 200 g/kg (wet basis), was evaluated by 80 non-trained panelists for appearance, color, taste and aroma on a 9-point hedonic scale (1 = "disliked extremely"; 9 = "liked extremely"). Samples were randomly coded with three-digit numbers and their order of presentation was completely randomized for each panelist. Partitioned booths with fluorescent lighting were used for evaluation and these were located in Sensory Evaluation Laboratory of the Domestic Sciences Department, Federal Rural University of Pernambuco (Recife, Brazil). This study was conducted in accordance with the ethical guidelines established by Brazilian legislation for researches using humans and it was registered in the Brazilian Ministry of Health at the Brazil Platform (CAAE:42586815.0.0000.5208).

2.8. Statistical analysis

For the physicochemical characteristics evaluated, an analysis of variance (ANOVA) was applied to analyze the results in order to determine if there were significant differences among samples. Means were compared by Tukey's test at $p < 0.05$. Data were