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Influence of air drying properties on non-enzymatic browning, major bio-active compounds and antioxidant capacity of osmotically pretreated papaya

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ABSTRACT

This study aimed to investigate the effect of air drying parameters such as temperature, specific humidity and velocity, on non-enzymatic browning behaviour and on bio-active compounds and antioxidant properties of osmotically pretreated papayas. Convection drying was conducted under through-flow mode at four temperatures (50, 60, 70, 80 °C), three air velocities (0.2, 0.5, 0.7 m/s) and two specific humidity levels (10, 25 g/kg dry air). Higher drying temperatures resulted in a significant decrease in moisture content and polyphenol oxidase activity, while degree of browning and 5-hydroxymethylfurfural increased. The antioxidant activity and total phenolic compounds increased with temperature and as well with decreasing air velocity. In contrast, specific humidity did not have a major effect on quality attributes of dried samples, except for carotenoid contents. This study has shown that drying parameters can decompose and/or enhance carotenoids contents in dried papayas. To obtain the product with highest level of bio-active compounds and lowest possible melanoid formation, treatment with temperature of 70 °C, specific humidity of 10 g/kg dry air and velocity of 0.2 m/s proved to be the most suitable option. Based on these results, optimization of the process, particularly drying temperature, should be considered with respect to preserving product colour and biochemical properties.

1. Introduction

Lately, emphasis on the importance of fruit and vegetable consumption has increased considerably, since they are naturally rich in various beneficial antioxidant compounds such as polyphenols, carotenoids and vitamins. Many experimental, clinical and epidemiological studies have exemplified that fruits and vegetables show a protective effect against cancer as well as neurological and cardiovascular diseases. This effect is due to their biochemical properties such as free radical scavengers, hydrogen donors, singlet oxygen quenchers and metal ion chelators (Ikram et al., 2009; Vega-Gálvez et al., 2009).

Papaya (*Carica papaya* L.) is an important source of functional nutrients such as minerals (calcium, iron, potassium, sodium), vitamins (A, B_1, B_2, C), and carotenoids (lycopene, β-carotene, β-cryptoxanthin). Schweiggert, Steingass, Mora, Esquivel, and Carle (2011) reported that the total carotenoid levels in fully ripened 'Costa Rican hybrid' papaya ranged from 5.42 to 6.21 mg/100 g of fresh weight. In addition, Gayosso-García Sancho, Yahia, and González-Aguilar (2011) also stated that average carotenoid contents of 3.27 mg/100 g of fresh weight were found in ripe 'Maradol' papaya. Carotenoids are known to be a substantial intermediate in biosynthesis of vitamin A. Diets rich in these phytochemicals can help to prevent vitamin A deficiency, which is a serious global nutrition problem, especially in young children and pregnant women from lower per capita income countries (WHO., 2009, pp. 1–18). Moreover, papaya also has a high demand in international markets. World papaya production and import values have been continually increasing over the past years, reaching 11.8 million tons and 243 million US dollars, respectively in 2010 (FAOSTAT, 2013). However, post-harvest losses of papaya occur along the entire value chain due to rapid deterioration of its chemical components, which results in a short shelf life of the fresh product.

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Dehydration is one of a few preservation methods to extend the storability of papaya. However, it is well known that fruits and vegetables undergo physicochemical alterations during hot air drying such as volume shrinkage, case hardening and discolouration. Many reactions can affect colour changes during thermal processing of fruits and vegetables, i.e. enzymatic and non-enzymatic reactions and degradation of carotenoids and chlorophylls. Additionally, the loss of carotenoids reduces the nutritional value, which makes it a particular concern. Considerable reductions of bio-active compounds during drying of various fruits and vegetables have been reported. Mostly, the loss of these beneficial compounds depends on drying parameters, especially temperature. Bennett et al. (2011) and Mrad, Boudhrioua, Kechaou, Courtois, and Bonazzi (2012) described that high drying temperature can lead to a complete loss of phenolic compounds in several fruits. However, some contrasting results have been reported concerning the influence of drying temperature on functional compounds. Dewanto, Wu, Adom, and Liu (2002) and Gahler, Otto, and Böhm (2003) claimed that total phenolic and carotenoid contents of tomato increased during thermal processing at high temperatures. This was reportedly due to hydrolysis of flavonoid glycosides and/or release of cell wall phenolics. Vega-Gálvez et al. (2009) observed an increase of antioxidant capacity at high drying temperatures in red pepper. This incident might be explained by generation and accumulation of Maillard-derived melanoidins that could also enhance antioxidant properties.

Ultimately, the challenge in modern food technology is not only to minimize chemical degradation reactions, but also to maximize retention of beneficial nutrients during processing. Although the effects of drying processes on product quality are well documented, few studies have focused on papaya in particular. El-Aouar, Azoubel, and Murr (2003) studied drying kinetics of fresh and osmotically pretreated papaya cubes. Fernandes, Rodrigues, Gaspareto, and Oliveira (2006) determined influences of osmotic dehydration followed by air drying on quality alterations of papaya. Loss, Santos, Muniz, Proveti, and Porto (2011) developed finite difference solutions for heat transfer kinetics during drying of cubic papaya particles. In addition, the effect of glass transition phenomenon on shrinkage of fresh papaya during convective drying has been reported by Kurozawa, Hubinger, and Park (2012). Nevertheless, no previous studies have investigated nutritional losses related to drying of osmotically pretreated papaya. Therefore, the objectives of this study were to investigate effects of different drying parameters (temperature, specific humidity, air velocity) on non-enzymatic browning behaviour and bio-active compounds properties, particularly antioxidant and carotenoid contents of papaya samples after dehydration.

2. Materials and methods

2.1. Raw materials

Papayas (*Carica papaya* L. cv. Pluk Mai Lie) obtained from a commercial orchard in Nakhon Nayok province, Thailand, were purchased from a local import company, and selected in order to get samples with uniform shape, fruit weight (1.0 ± 0.2 kg), ripening stage (70 ± 10% of yellowness skin), moisture content (85.2 ± 1.1 g water/100 g), soluble solids content (10.2 ± 0.3 °Brix), titratable acidity (0.1 ± 0.0 g citric acid/100 g) and pH (5.2 ± 0.2). During experiment, the fruits were refrigerated at a temperature of 10 ± 1 °C for not more than 5 days.

2.2. Sample preparation

2.2.1. Osmotic pretreatment

The samples were treated osmotically according to the procedure described in a previous study (Udomkun, Mahayothee, Nagle, & Müller, 2014). Papayas were hand-peeled and cut into dimensions of 20 × 30 × 20 mm using a specially-designed stainless steel cutter. The samples (600–650 g of cut fruit pieces) were rinsed with fresh water and then soaked in 2.5 g/100 g calcium lactate ($Ca \cdot C_6H_{10}O_6$) solution. The samples were allowed to soak for 1 h at controlled temperature (20 ± 2 °C), then blanched at 60 ± 2 °C for 1 min. Subsequently, they were immersed in a hypertonic solution of 30 °Brix a starting temperature 60 ± 2 °C and allowed to stand at room temperature for 6 h. The osmotic solution was prepared by dissolving 99.9% refined sucrose in water to obtain the required concentration and then pH was adjusted to 4.0 using citric acid. The weight ratio of osmotic solution to fruit samples was 1:1. After removal from the solution, the samples were rinsed with water, drained and blotted with absorbent paper to remove the surface water before drying.

2.2.2. Convection drying

After pretreatment, papaya samples were placed on a round 24 cm diameter perforated dryer tray. Convection drying was conducted using the through-flow chamber of a high-precision hot air laboratory dryer (Institute of Agricultural Engineering, Tropics and Subtropics Group, Universität Hohenheim, Germany). A description of the experimental dryer has been given by Argyropoulos, Heindl, and Müller (2011) and Argyropoulos, Khan, and Müller (2011). Different drying temperatures (50, 60, 70, 80 °C), specific humidities (10, 25 g water/kg dry air) and air velocities (0.2, 0.5, 0.7 m/s) were applied. The experimental code for a drying condition, for example 50/10/02, describes drying temperature, specific humidity and air velocity, respectively. Mass reduction was automatically recorded during the dehydration process for establishing the drying curves and determination of total drying time. Papaya samples were dried until the moisture content reached 13.5 ± 0.1 g water/100 g. Experiments were performed in triplicate. Final samples were packaged and sealed in polyethylene film bags and were stored under dark conditions at −20 °C before physicochemical analyses, except samples for carotenoids analysis that were kept at −80 °C.

2.3. Chemical analyses

2.3.1. Chemicals and solvents

The compounds of 5-hydroxymethylfurfural (HMF), 2,2-diphenyl-1-picrylhydrazyl (DPPH), 2,4,6-tripiridyl-*s*-triazine (TPTZ), 2,2-azinobis-3-ethyl-benzothiazoline-6-sulfonic acid (ABTS), 2,2′-dipyridyl, L-3,4-dihydroxyphenylalanine (L-DOPA), Folin–Ciocalteu's reagent, and all standards of gallic acid, 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox), lycopene, β-cryptoxanthin, β-carotene, and β-apo-8′carotenal were purchased from Sigma Aldrich Chemie GmbH (Taufkirchen, Germany). Butylated hydroxytoluene (BHT) was supplied by Fluka Chemie GmbH (Buchs, Switzerland). The HPLC-grade and other reagent grade solvents were acquired from Roth Chemie GmbH (Karlsruhe, Germany). Deionized water was used throughout.

2.3.2. Basic chemical analyses

Moisture content (MC) was determined as g water/100 g using Karl Fischer titration (model 758 KFD Titrino, Metrohm GmbH and Co., Herisau, Switzerland). Water activity (a_w) was measured using a ventilated hygrometer system (model AW-DIO, Rotronic, Bassersdorf, Switzerland) after 20 min in a thermostatic cell at 25 °C. Results are given as water activity (% ERH/100). Total soluble solids (TSS) were measured using a refractometer (model PR-201, Atago, Tokyo, Japan). Titratable acidity (TA) expressed as g citric acid/100 g sample was determined by alkaline titration method with 0.1 mol/L NaOH to obtain pH 8.1 (AOAC., 2006). The pH of samples was