Innovative Food Science and Emerging Technologies 11 (2010) 39–46

Contents lists available at ScienceDirect

Innovative Food Science and Emerging Technologies

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

Colour and texture of apples high pressure processed in pineapple juice

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ARTICLE INFO

Article history:
Received 6 March 2009
Accepted 3 August 2009

Keywords:
High pressure processing
Minimal processing
Enzymatic browning
Texture
Pineapple juice
Apples

ABSTRACT

Cubes of Granny Smith and Pink Lady apples were vacuum packed in barrier bags with 0% to 50% (v/v) pineapple juice (PJ) at 20°Bx and subjected to high pressure processing (HPP) at 600 MPa for 1–5 min (22 °C). The in-pack total colour change (Δ*E*) was observed over 4 weeks at 4 °C. Within <1 week of storage at 4 °C, texture, polyphenoloxidase, pectinmethylesterase activities, changes in Δ*E* and visual browning after opening the bags during air exposure (22 °C; 21% O2) for 5 h were also monitored. During the 4 weeks storage in bag visible colour changes were not observed. Texture and Δ*E* after 5 h air exposure were significantly affected by the apple variety, HPP time and % PJ used. The combined treatment significantly reduced residual PPO activity while PME activity was not affected in both varieties. Pineapple juice in combination with HPP could be used as a natural preservation system for minimally processed apples. *Industrial relevance:* Browning upon opening the packs and during air exposure can adversely affect the quality of fresh-cut fruits. Combined treatment of high pressure processing (HPP) and use of pineapple juice has the potential to prevent browning for several hours giving sufficient time for presentation and use in domestic and foodservice environment where high quality fresh-like fruit is required.

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1. Introduction

Consumers demand high quality, convenient minimally processed natural fruit products with fresh appearance, texture and flavour, which are free from preservatives and other additives. However, minimally processed fresh products have a relatively short shelf life due to wounding related to increased metabolism (King & Bolin, 1989; Joan & Kader, 1989; Watada, Abe & Yamuchi, 1990; Varoquaux, Mazollier & Albagnac, 1996; Paull & Chen, 1997) and microbial spoilage. Physiological and biochemical changes in such products occur at a faster rate than in intact fruits resulting in the rapid onset of enzymatic browning (Brecht, 1995; Buta & Abbott, 2000) and excessive tissue softening (Toivonen & DeEll, 2002). Enzymatic browning and the resultant discolouration of cut fruit products, upon exposure to air, is a major problem for the food industry impairing not only the colour of fresh-cut fruits but also the flavour and the nutritional quality (Rigal, Cerny, Richard-Forget & Varoquaux, 2001). Mainly the browning is developed due to enzymatic oxidation of phenols to quinones by polyphenoloxidase (PPO) in the presence of oxygen. Subsequently, these quinones condense and react non enzymatically with other substances such as phenolic compounds and amino acids to produce complex brown polymers. Sulfites are extensively used as PPO inhibitors to prevent enzymatic browning in fruit products. However, sulfites are reported to induce adverse allergenic effects in certain sensitive individuals such as asthmatics (Sapers, 1993). Other additives including, 4-hexylresorcinol, cysteine, acidulants and chelating agents such as citric acid and phosphates are able to reduce enzymatic browning, but they are usually less effective than sulfites (Janovitz-Klapp, Richard & Nicolas, 1989).

There is an increasing demand by consumers for substituting preservatives and any other additives with natural substances (Jang, Sanada, Ushio, Tanaka & Ohshima, 2002). Compounds of inherently natural origin would be widely accepted by consumers in the market. This consumer demand has stimulated the search for natural and safe antibrowning agents and processing methods that can result products with high quality, acceptable appearance, flavour and nutritional value in addition to the microbiological safety.

High pressure processing (HPP) offers a natural, environmentally friendly alternative for pasteurisation and shelf life extension of a wide range of food products (Welti-Chanes et al., 2005). HPP in combination with packaging of good barrier properties can prevent browning in minimally processed products during storage in the sealed pack. However, due to only partial inactivation of the PPO enzyme it is not possible to prevent browning when the packs are opened and the products are exposed to air. The use of pineapple juice to inhibit enzymatic browning was investigated by others previously (Lozano-de-Gonzalez, Barrett, Wrolstad & Durst, 1993). It was reported that pineapple juice and ion-exchange fractions of pineapple juice were both equally effective as sulfite in the inhibition of enzymatic browning in fresh and dried apple rings. The best results were achieved in

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doi:10.1016/j.ifset.2009.08.003

browning prevention with the cation-exchanged fraction of pineapple juice. Wen and Wrolstad (1999) reported that a non volatile organic acid in pineapple juice was the major inhibitor of enzymatic browning in apple products. Labuza, Lillemo and Taoukis (1990) investigated the effect of proteolytic enzymes of plant origin on enzymatic browning inhibition. They found that ficin and papain were comparable to sulfite in prevention of browning in potatoes and apples. However, bromelain was effective only on apples during storage at 4 °C. McEvily (1991) reported that a ficin free extract prepared from the fig latex can inhibit enzymatic browning in apple and shrimp. There is no published research on the effectiveness of pineapple juice in combination with HPP as an inhibitory system for the prevention of enzymatic browning. This study was aimed to investigate the combined effect of HPP treatment and pineapple juice on some physicochemical parameters. Investigated were the treatment effects on total colour change during storage and upon exposure to air, textural changes and quality related enzymes (PPO and PME) in minimally processed Granny Smith and Pink Lady apples.

2. Materials and methods

2.1. Plant materials

Granny Smith, Pink Lady apples and Smooth Cayenne pineapples were obtained from a local supermarket. Selected pineapples had a shell colour of half to three-fourths gold as described in Dole's fresh pineapple colour standard guide. Firmness was measured with a hand-held fruit pressure tester, (FT 327, Italy; 8 mm probe). Granny Smith and Pink Lady apples had a firmness of 3.5 and 4.5 kg respectively. The total soluble solids (Deta refractometer Bellingham and Stanley Ltd.) of the Granny Smith and Pink Lady apples were 13° and 15°Bx respectively.

2.2. Pineapple juice preparation

Pineapples were peeled and the juice was extracted with a small bench top juice extractor (Nutrifaster Model Ruby 2000, USA). Single strength pineapple juice (12°Bx) was diluted with distilled water (v/v) to obtain 25% and 50% pineapple juice. The dissolved solids concentration of the 25 and 50% pineapple juices were adjusted to 20°Bx by the addition of food grade sucrose (CSR, Australia). The pH of the different concentrations of pineapple juice was maintained at 3.6.

2.3. Preparation of apple cubes

Apples were washed with a solution of 200 ppm chlorine (100 mL of Milton solution in 8 L potable water Milton, Australia). Washed apples were peeled and cored manually and mechanically diced into 1 cm^3 pieces using a small bench top Anliker dicer (Anliker, Australia). The fruit pieces were held in a 0.1% (w/v) ascorbic acid solution (Robert Bryce and Company, Ltd., Australia) prior to packaging to prevent surface browning. Diced fruit pieces (200 g) were drained in a plastic strainer and packed into high oxygen barrier upright flexible retort pouches (Amcor, Germany; oxygen permeability: 2 cm^3/1 m^2/24 h package size 14 cm × 18.5 cm) with 100 mL 20°Bx pineapple juice at concentrations of 0, 25 and 50% (v/v). Fruit pieces in 20°Bx sugar solution were used as the control (0% pineapple juice). The pouches were vacuum-sealed at −0.8 bar using the Webo-Matic E50G, vacuum packaging machine (Warner Bonk, Bochum).

2.4. High pressure processing

Samples were treated in a 35 L high pressure vessel (Flow Pressure System QUINTUS® Food Press Type 35 L-600 sterilization machine Avure Technologies, Kent, WA, USA) at 600 MPa, at ambient temperature (18–22 °C) for 1, 3 and 5 min. The samples and the pressurising medium (water) were kept at a pre-determined initial temperature to obtain the expected processing temperature during compression. The initial temperature of the samples processed at 600 MPa and 22 °C were maintained at 7 °C. The compression rate was 4.2 MPa/s while the decompression rate was 40 MPa/s. Six hundred MPa pressure is considered to be economical and microbiologically safe at the pasteurisation level (Suthanthangjai, Kajda & Zabetakis, 2005). Pressure treated samples and untreated controls were stored at 4 °C for one month in styrofoam boxes, without exposure to light.

2.5. Total colour change (ΔE)

The in-pack colour (L^*, a^* and b^* values) of triplicate samples was measured through the transparent retort pouch at weekly intervals over 4 weeks using a Minolta Chroma Meter CR-300 (Minolta Corp., Osaka, Japan).

Apple samples stored for <1 week at 4 °C were used for the air exposure study. The most prominent colour changes were observed at the end of the 5 h of air exposure. Therefore the total colour change after 5 h of air exposure (with triplicate samples) is discussed in this publication. The total colour change (ΔE) was calculated with the following equation (Hunter Lab, (1996)): $\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}$.

2.6. Visual browning score

The visual browning score was developed based on the browning of the control samples (diced pieces) of each apple variety. The samples were scored for acceptability of colour with visual browning score system developed according to the 9-point hedonic scale ranging from 1 to 9 based on the severity of browning (visual browning score: 1—excellent, 2—highly acceptable, 3—acceptable, 4—moderately acceptable, 5—neither acceptable nor unacceptable, 6—moderately unacceptable, 7—unacceptable 8—highly unacceptable and 9—completely unacceptable). The visual browning score system was used to assess the samples during air exposure and visual ratings were allocated immediately after exposure and every hour over the 5 h period using triplicate of samples.

2.7. PPO extraction and assay

PPO activity was determined from samples within <1 week of storage at 4 °C. The PPO enzyme was extracted from apples using the method described by Gauillard and Richard-Forget (1997) and Carbonaro and Mattera (2001) with some modifications. All the chemicals that were used in the extraction and assay of the enzymes were of analytical grade or higher degree of purity. Freeze-dried apple samples (6 g) were homogenized with 50 mL of McIlvaine citric acid phosphate buffer, (pH 6.5, containing 0.05 M sodium dodecyl sulphate, Sigma-Aldrich) using an Ultra Turrax T_{25} homogeniser (IKA Labotechnik, Germany) at 9500 rpm for 2 min. All subsequent steps were also performed at 4 °C. The zsuspension was centrifuged at 3000 × g for 15 min followed by 23,700 × g for 15 min. The supernatant was filtered through Whatman No. 4 filter paper and used as the enzyme extract to determine PPO activity.

The PPO activity was determined in a reaction mixture (152.5 μL) containing 50 μL enzyme extract, 90 μL 0.1 M citric acid phosphate buffer (pH 6.5) and 12.5 μL caffeic acid (90 mg caffeic acid/100 mL citric acid phosphate buffer, pH 6.5) in a micro well plate. The absorbance of the mixture was measured at 420 nm for 10 min at 30 s intervals at 37 °C using a spectrophotometer (SpectraMax Plus^{384} Molecular Devices Corporation, Sunnyvale CA, USA). One unit of PPO activity was defined as a change in absorbance of 0.001 OD/min. The reaction rate was estimated from the initial linear portion of the plotted curve. The relative PPO activity of the samples was calculated by % PPO activity = $A_t/A_o \times 100$, where A_t = PPO activity of high

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