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Effect of hydrostatic high pressure processing on nectarine halves pretreated with ascorbic acid and calcium during refrigerated storage

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A B S T R A C T

The effect of the level of pressure applied during high pressure processing (HPP) on nectarine halves pretreated with ascorbic acid (2 g/100 mL) (AA) and ascorbic acid (2 g/100 mL) plus calcium lactate (1 g/100 mL) (AA + Ca) was studied. *Honey* spp. nectarines (*Prunus persica*) were cut in halves and they were vacuum packed in thermo-sealed plastic bags. One nectarine half was HP-treated while the other was non-treated, so each nectarine half was compared with the other one in order to assess the effect of the intensity of pressure applied (200, 300, 400, 500 and 600 MPa at 10 °C for 3 min). After HPP, fruits were refrigerated at 5 °C for 30 days. pH, acidity, soluble solids content, firmness and CIELab colour parameters were evaluated after 1 and 30 days of storage. The pH decreased as a consequence of the ascorbic acid and calcium lactate addition while the soluble solids content and the acidity were neither affected by the pretreatment nor by HPP. HPP induced important colour and texture changes in the nectarine halves, although at 200–300 MPa the modifications were less intense. AA and AA + Ca pretreatments had a protective effect on colour and firmness but only at low pressure intensities.

1. Introduction

Texture and colour are deciding factors for consumers' acceptability of fruit. High pressure processing (HPP) is an interesting alternative to traditional preserving methods. This technology minimizes quality modifications of processed products. HPP could preserve the nutritional value and the delicate sensory properties of fruits and vegetables (Ramírez, Saraiva, Pérez Lamela, & Torres, 2009) due to its limited effect on the covalent bonds of low molecular-mass compounds such as colour and flavour compounds. However, other studies have shown that HPP can alter some physical–chemical properties of fruits and vegetables matrices by inducing important changes in their original structure (Basak & Ramaswamy, 1998; Préstamo & Arroyo, 1998; Tangwongchai, Ledward, & Ames, 2000). Food is a complex system and the compounds responsible for sensory properties coexist with enzymes, metal ions, etc. In fact, HPP (100–1000 MPa) promotes (i) cell wall and membrane disruption; (ii) enzyme catalysed conversion processes; (iii) chemical reactions and (iv) the modification of biopolymers, including enzyme inactivation, protein denaturation and gel formation which can occur simultaneously implying textural and colour changes (Oey, Lille, Van Loey, & Hendrickx, 2008).

In fruits and vegetables, the application of HPP could be an adequate method to preserve the textural characteristics of vegetables due to the limited damage on tissues and the reduced biochemical changes compared to the traditional thermal treatment (Islam & Igura, 2003). The changes on the texture of HP-treated products depend on the processing conditions (pressure, holding time and temperature) but also on the type of fruit cell. HPP affects the organization of the cells parenchyma as internal air present in the natural structure of fruits is compressed during the treatment. The plant cells collapse and the intercellular spaces are no longer filled with gas. After HPP, cavity formation occurs and a firm texture and a soaked appearance are noticed. Cell integrity disruption has been observed by Cryo-SEM microscopic in spinach and cauliflower (400 MPa, 5 °C, 30 min) (Préstamo & Arroyo, 1998) and it promotes the occurrence of enzymatic and non-enzymatic reactions since substrates, ions and enzymes located in different compartments in the cells can react with each other (Sila et al., 2007). Pressure can enhance the action of pectinmethylesterase,

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lower the polygalacturonase activity (occurring mostly at moderate temperature), and retard the β-elimination, however, fruit pectinases show differences in their pressure and temperature stability depending on the type of vegetable (Ly Nguyen et al., 2002; Nunes et al., 2006; Van den Broeck, Ludikhuyze, Van Loey, & Hendrickx, 2000). As a consequence, different pressure and temperature combinations can be used to activate or inactivate some specific pectinases during processing. In several fruits and vegetables, such as apple, pear, orange, pineapple, carrot, celery, green pepper and red pepper, a loss of texture was found at 200–400 MPa (room temperature, 5–60 min) (Basak & Ramaswamy, 1998). In cherry tomatoes, pressures from 200 to 400 MPa (20 °C, 20 min) resulted reduced the quality of tomatoes while pressures greater than 400 MPa (500 and 600 MPa, 20 °C, 20 min) led to a less apparent damage in textural parameters (Tangwongchai et al., 2000). However, for industrial application holding times longer than 10 min are generally too long and shorter holding times need to be studied in order to recover the initial investments.

Calcium treatments have been used to extend the shelf-life of fruits and vegetables since calcium ions form cross-links or bridges between free carboxyl groups of the pectin chains, resulting in strengthening of the cell wall (García, Herrera, & Morilla, 1996). Calcium complexes go to the polygalacturonic acid residues of the cell wall and the middle lamella, improving structural integrity (Van-Buren, 1979). As a result, the fruits and vegetables treated with calcium usually remain firmer during storage than those non-treated (Duvetter et al., 2005; Sila, Smout, Vu, & Hendrickx, 2004). Calcium lactate (0.5–2 g/100 mL) has been used as a firming agent. It is a good alternative to calcium chloride as it avoids the undesirable bitterness associated with this salt (Luna-Guzmán & Barrett, 2000; Varela et al., 2007).

The changes of colour in HP-treated fruits and vegetables could be ascribed to textural modifications that may result in changes in the nature and the extent of the internally scattered light. After HPP, the changes in the appearance are mostly caused by variations in the internal structure of fruits than by modifications in the pigment concentration (MacDougall, 2002). In fact, at low and moderate temperatures, HPP has a limited effect on the main pigments responsible for the colour of fruits and vegetables (García-Palazon, Suthanthangjai, Kajda, & Zabetakis, 2004; McInerney, Cathryn, Seccafien, Stewart, & Bird, 2007; Patras, Brunton, Da Pieve, & Butler, 2009). However, the changes in the structure and pigmentation of food interact with each other to affect both colour and translucency/opacity.

Immediately after HPP, instrumental colour parameters (CIE L*, a* and b* values) of fruit-based products, such as juices or purées, are rather unaffected (Ahmed, Ramaswamy, & Hiremath, 2005; Daoudi et al., 2002). By contrast, colour pigments of HP-treated fruits and vegetables can change during storage due to the incomplete inactivation of enzymes and microorganisms, which can result in undesired chemical reactions (both enzymatic and non-enzymatic) in the food matrix (Kouniaki, Kajda, & Zabetakis, 2004). Browning plays an important role in the colour modifications of HP-treated food products due to enzyme incomplete inactivation. This fact has been reported (Guerrero-Beltrán, Swanson, & Barbosa-Canovas, 2005) in pressurized mango purée. Ascorbic acid (L-ascorbic acid) has been the leading Generally Recognised as Safe (GRAS) antioxidant for use on fruit-based food products for the prevention of browning and other oxidative reactions (Bauernfeind & Pinkert, 1970). Ascorbic acid (AA) also acts as an oxygen scavenger, removing molecular oxygen in polyphenoloxidase reactions, and the inhibition of polyphenoloxidase has been attributed to the reduction of enzymatically formed o-quinones to their precursor diphenols.

The effect of the level pressure applied on parameters such as the colour and texture of fruits is not known in depth. In addition, the utilization of preservatives such as calcium and/or ascorbic acid could not be adequate or effective in high pressure treated products. HPP could be an alternative to extend fruit shelf-life and these factors have not been assessed. Therefore, the main objectives of this study were (i) to evaluate the effect of the pressure level on nectarine halves quality and (ii) to assess the efficacy of ascorbic acid (AA) and ascorbic acid plus calcium lactate (AA + Ca) pretreatments on the quality attributes of HP-treated nectarines after processing at industrial conditions and after 30 days of refrigerated storage.

2. Material and methods

2.1. Material

Honey spp. nectarines (*Prunus persica*) were taken from a packinghouse in Extremadura region (South West of Spain) in the summer of 2009. In the Technological Agri-Food Institute (INTAEX, Badajoz, Spain), fruits were washed with 100 mg/L of sodium hypochlorite and then they were rinsed. Nectarines were cut in halves (Fig. 1), avoiding the stone, and they were dipped in water (control, non-pretreated), ascorbic acid (2 g/100 mL) (AA) (Brenntag Química S.A, Seville, Spain) and ascorbic acid (2 g/100 mL) plus calcium lactate (1 g/100 mL) (AA + Ca) (Panreac Química S.A.U., Spain) solutions for 10 min at 5 °C. Afterwards, fruits were drained with blotting paper and vacuum packed in thermo-sealed plastic nylon/polyethylene bags (9.3 mL O_2 m^{-2} 24 h^{-1} at 0 °C, Mod. COEX3-soldas, Plasacar S.L., Sevilla, Spain). A total of 7 nectarines were analyzed in each batch (Pretreatment × HPP). One nectarine half was HP-treated while the other was non-treated, so each nectarine half could be compared with the other one in order to evaluate the effect of pressure level, regardless the individual differences of the fruit.

2.2. HP treatment and refrigerated storage

HPP took place in a semiindustrial high pressure unit (Hyperbaric Wave 6000/55, Burgos, Spain). Five levels of HP treatments were applied (200, 300, 400, 500, 600 MPa) for 3 min with an initial water temperature of 10 °C. Times to reach 200, 300, 400, 500 and 600 MPa were 110, 144, 174, 202 and 230 s, respectively. HPP effect

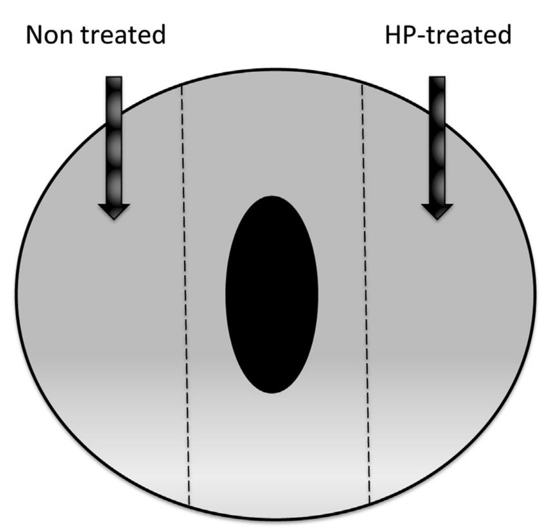

Fig. 1. Sampling procedure to the study of the effect of HPP on nectarine halves.