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Impact of combined ascorbic acid/$CaCl_2$, hydrogen peroxide and ultraviolet light treatments on structure, rheological properties and texture of fresh-cut pear (William var.)

Analia B. Garcia Loredo [a,c], Sandra N. Guerrero [a,b], Stella M. Alzamora [a,b,*]

[a] Departamento de Industrias, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Intendente Guiraldes s/n., Ciudad Universitaria, (1428) C.A.B.A., Argentina
[b] Member of Consejo Nacional de Investigaciones Científicas y Técnicas, de la República Argentina
[c] Fellowship of Consejo Nacional de Investigaciones Científicas y Técnicas, de la República Argentina

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ABSTRACT

This work aimed to evaluate and correlate rheological properties (dynamic oscillatory, creep/recovery and double compression tests), texture (sensory evaluation) and structure (optical and transmission electron microscopy observations) of fresh-cut pear as affected by ascorbic acid/$CaCl_2$ dipping, hydrogen peroxide and short-wave ultraviolet light radiation (UV-C). All pear samples showed a solid behavior ($G' > G''$), but both dynamic moduli decreased in response to the treatments. For treated tissues, the instantaneous elastic (J_0) and the retarded (J_1, J_2) compliances increased, while the steady-state viscosity (η_N) and all mechanical parameters decreased. PLS regression models revealed that texture could be well explained by rheological properties. Deformability modulus (E_d) was positively correlated to sensory fracturability and hardness and negatively correlated to juiciness. J_0, J_1 and J_2 were negatively related to sensory hardness. Compression and creep parameters evidenced changes in structure (mainly rupture of membranes, degradation of middle lamella and cell walls) of surface tissues.

1. Introduction

Development of new technologies to minimize microbial risk while preserving the fresh-like characteristics of fruits is crucial to satisfy the increasing demand for ready-to-eat products (Soliva-Fortuny and Martín-Belloso, 2003). A good procedure to reduce microbial risk involved in the consumption of fresh-cut fruits and/or extend their shelf life includes the reduction or elimination of microbial load by using emerging decontamination techniques, like high hydrostatic pressure, pulsed electric field, pulsed light, ultrasound and short-wave ultraviolet light (Gómez et al., 2011a).

UV-C is a radiation in the range of 200–280 nm which cross DNA pyrimidine bases of cytosine and thymine, impairing formation of hydrogen bonds with the purine base pair on the complimentary strand of DNA and thus reproduction of microorganisms (Bintsis et al., 2000; Shama, 2006). It has also been proved to cause significant damage in the cytoplasmic membrane integrity and in the cellular enzyme activity (Schenk et al., 2011). Hydrogen peroxide (H_2O_2) is a strong oxidizing proposed as an alternative to decontaminate fruits and vegetables due to its low toxicity and safe decomposition products. It is effective against a wide spectrum of bacteria, yeast, molds, viruses and spore-forming organisms (Cords et al., 2005). H_2O_2 has been shown to damage bacterial proteins, DNA and cellular membranes of microbial cells and to remove protein from the coat of the bacterial spores (Juven and Pierson, 1996). H_2O_2 is classified as GRAS to be used in food products as a bleaching, oxidizing and reducing agent and antimicrobial agent (Sapers and Miller, 1998). Combining (UV-C) irradiation and H_2O_2 has been applied successfully in industrial sterilization or disinfection processes and in food preservation. Both processes in combination have been reported to show a synergistic action. Waites et al. (1988) suggested that the mechanism for UV-C–H_2O_2 synergy is mainly related to enhanced production of hydroxyl radicals from H_2O_2 due to irradiation.

During minimal processing, mechanical injury results in cellular delocalization of enzymes and their substrates, leading to biochemical deteriorations such as enzymatic browning, off-flavors and texture breakdown, as well as increased respiration rate and ethylene synthesis. Enzymatic browning, caused mainly by the action of polyphenol axidase (PPO), is a major effector limiting the shelf-life of minimally processed fruits (Lamikanra, 2002). Ascorbic acid as a reducing agent has for long been applied in combination with organic acids or calcium salts to prevent enzymatic browning

* Corresponding author at: Departamento de Industrias, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Intendente Guiraldes s/n., Ciudad Universitaria, (1428) C.A.B.A., Argentina. Tel.: +54 (0)11 45763366.
E-mail addresses: alzamora@di.fcen.uba.ar, smalzamora@gmail.ar (S.M. Alzamora).

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and maintain firmness of fruits (Lamikanra, 2002; Wang et al., 2007). Recently, Gomez et al. (2010) and Schenk (2010) found that the application of an antibrowning pretreatment containing 1% (w/v) ascorbic acid – 0.1% (w/v) calcium chloride helped in maintaining the original color of apple and pear slices after UV-C light exposure respectively.

Effects of UV-C light, alone or combined with other treatments, on quality attributes (texture, flavor, color) and microbial response is quite diverse depending on the type of produce and the dosages applied (Shama, 2006; Charles and Arul, 2007). Gómez et al. (2010) examined the effect of UV-C irradiation at different doses on surface color of apple slices stored in refrigeration for 7 days. They also explored the use of some pretreatments (hot water blanching, dipping in a solution containing ascorbic acid and calcium chloride) to minimize apple browning caused by UV-C light. Color parameters were found to be dependent on UV-C dose, storage time and type of pretreatment. Both pretreatments contributed to maintain the original color of apple slices after UV-C light exposure. Gómez et al. (2011b) studied the effect of UV-C (11.2 kJ/m^2) combined with an antibrowning pretreatment on texture, rheological properties (viscoelastic and mechanical properties) and structure of apple slices during refrigerated storage. Overall, both dynamic moduli decreased, and instantaneous compliance, decay compliances and fluidity significantly increased after treatments and storage at 5 °C. However, texture attributes (hardness, fracturability, juiciness and crispness) of fresh apple and apple dipped into the antibrowning solution and then UV-C irradiated did not show significant differences after 5 days refrigerated storage. Recently, Schenk et al. (2012) demonstrated that immersion of pear slices in 3% v/v H_2O_2 solution (300 s) in combination with UV-C irradiation (3.7 kJ/m^2, 450 s) achieved significant reductions in *Escherichia coli*, *Listeria inocua* and *Zygosaccharomyces bailii* populations (2.4–3.6 log red.). They also examined surface color and texture of pear slices during refrigerated storage (8 days). During storage, processed samples with the combined treatment (H_2O_2/UV-C) turned darker than control samples and this effect was more pronounced in pear discs treated with UV-C treatment alone. The combined treatment kept optimal microbial stability and exhibited a greater value of the CIE L* parameter (lightness) than the UV-C treatment alone. Texture profile analysis conducted using a trained panel showed that H_2O_2/UV-C processed pear discs were perceived with significantly less hardness and fracturability but as juicy as untreated discs.

It is well known that mechanical properties of biologic tissues depend on contributions from the different levels of structure: the molecular level (i.e., the chemicals and the interactions between the constituting polymers), the cellular level (i.e., the architecture of the tissue cells and their interactions) and the organ level (i.e., the arrangement of cells into tissues) (Ilker and Szczesniak, 1990; Jackman and Stanley, 1995; Alzamora et al., 2008). At the cellular level, the three major structural aspects that contribute to textural properties of plant-based foods are turgor (the force exerted on the cell membrane by intracellular fluid), cell wall rigidity, and cell–cell adhesion, determined by the integrity of the middle lamella and the plasmodesmata (Ilker and Szczesniak, 1990; Alzamora et al., 2008). In recent years, several studies have been carried out in fruits and vegetables in an effort to understand the relationships between structure, texture and rheological changes induced by processing (Jack et al., 1995; Alzamora et al., 2008; Gómez et al., 2010, 2011b; Garcia Loredo et al., 2011).

The objectives of the present investigation were: (a) to analyze the rheological properties (derived from dynamic oscillatory, creep/recovery and double compression tests), texture attributes, and structure (by light and transmission electron microscopy observations) of fresh cut pear as affected by ascorbic acid/$CaCl_2$ dipping, hydrogen peroxide and ultraviolet light radiation; (b) to examine the correlations between rheological parameters and texture, using partial least square linear regression; and (c) to explore how differences in pear tissue structure were expressed by viscoelastic, mechanical and sensory parameters. This combined treatment (antibrowning solution/H_2O_2/UV-C) was aimed to reduce the potential contamination of "ready-to-eat" cut pear to be consumed within 1–2 days of refrigerated storage (catering industry, restaurants, schools) (Ahvenainen, 2000).

2. Materials and methods

2.1. Preparation of samples

Ripe pears (*Pyrus communis*, William cv; $a_w = 0.98 \pm 0.03$; 12.7 ± 1.0 °Brix; pH 4.0 ± 0.3) were purchased at a local market and maintained at 4–5 °C until use. Before being processed, whole fruit was washed in water, dipped into sodium hypochlorite solution (100 ppm free chlorine, 3 min) and rinsed in water. All cutting boards, tools and holding vessels were sanitized in the same way before use. Pears were hand peeled and slices of parenchymatous tissue were cut parallel to the axis through the calyx and the stem. The slices were cut out vertically with a cork borer to obtain 0.03 m in diameter and 0.01 m in thickness discs. All slices were taken from the middle part between the center and the surface of the fruit, where there were few vascular bundles. Pears discs were dipped in distilled water (4–5 °C) for 1 min to eliminate cellular fluids, slices were dried in tissue paper and immediately subjected to the different treatments to avoid the loss of moisture.

Ten measurements of the thickness were made at different points with a Teclock dial micrometer model SM-124 (±0.0001 m, Japan). Only slices with a standard deviation of the required thickness lower than 0.005 m were used.

The same lot of fruit was used in all the experiments to minimize the inherent variation due to age and/or cellular structure of the biological tissue, and the influence of agronomic practices and time of harvest in the field.

2.2. UV-C equipment and dosimetry

The UV-C irradiation device consisted of one bank of two reflectors with unfiltered germicidal emitting lamps (maximal emission at 253.7 nm, TUV-15 W G 13 T8 55 V, Philips, Holland) located 0.1 m above the produce tray. The UV-C lamps and the treatment area were enclosed in a wooden box covered with aluminum foil with a cover protection for the operators. A ventilation device was installed in a corner of the box to avoid temperature increase due to UV-C radiation. The average air temperature during the treatments was 27 ± 1 °C. Prior to use, the UV-C lamps were allowed to stabilize by turning them on at least 15 min.

The UV-C intensity emitted from the lamps was determined by using the iodure/iodate chemical actinometer (Rahn, 1997). All reactive employed in UV-C dosimetry were analytical grade from Merck Química Argentina S.A. (Argentina). The test was made by quadruplicate and the mean value was reported. Variations in radiation dose absorption were minimized by placing the samples within a uniform area of the radiation field (between the lamps and equidistant with respect to lamp extremes).

Based on previous study by Schenk et al. (2008), demonstrating the effectiveness of UV-C dose of 3.7 kJ/m^2 to inactivate spoilage microorganisms, this dose was applied to pear discs. Treatment application lasted 450 s.

2.3. Treatments

Pear discs were dipped into an antibrowning solution (DIP) containing 1% (w/v) ascorbic acid (food grade, Química Oeste S.A.,