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Impact of pulsed light treatments on quality characteristics and oxidative stability of fresh-cut avocado

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ABSTRACT

Fresh-cut avocado pieces were subjected to pulse light (PL) treatments on both sides (3.6, 6.0 and 14 J/cm^2 per side) with the purpose of evaluating their effect on the microbial burden, color, chlorophyll stability and lipid oxidation for 15 days of storage at 4 °C.

Exposure of fresh-cut avocado to the highest dose led to the highest reductions in aerobic mesophylic microorganisms (1.20 log CFU/g) and inhibited the proliferation of yeasts and molds for 3 days, prolonging their microbiological shelf life up to 15 days. Hue values of fresh-cut avocados were better maintained after applying PL treatments. This behavior was partially related with the high chlorophyll retention observed in the same PL-treated samples. In fact, an increment up to around 1.3-fold of chlorophyll *a* and *b* was observed after applying 6.0 J/cm^2 to fresh-cut avocados. The lipidic fraction of fresh-cut avocados subjected to PL treatments exhibited minimal peroxide formation and stable specific extinction coefficients at 232 and 272 nm for 15 days. These results indicate that the treatments did not result in an increase of rancidity processes, which remained at the induction stage.

1. Introduction

Avocado (*Persea americana* Mill.) is a fruit with an outstanding taste and creamy texture. Its lipidic content, which is predominantly constituted by monounsaturated fatty acids, provides potential health benefits in preventing cancer and cardiovascular diseases (Awad & Fink, 2000; Plaza, Sánchez-Moreno, De Pascual-Teresa, De Ancos, & Cano, 2009). Unfortunately, the shelf-life of avocado is severely determined by both microbial spoilage and oxidative processes (Elez-Martínez, Soliva-Fortuny, Gorinstein & Martín-Belloso, 2005; Wong, 1989, pp. 229–245; Yahia & Gonzalez-Aguilar, 1998). Most of the quality changes observed throughout storage of avocado pulp are the result of enzymatic browning, catalyzed by polyphenol oxidase, and lipid oxidation, involving the production of peroxides and other secondary products through an oxygen attack on the unsaturated fatty acids (Gunstone & Norris, 1982, pp. 95–139; Soliva-Fortuny, Grigelmo-Miguel, Odriozola-Serrano, Gorinstein, & Martín-Belloso, 2001). This process results in rancidity and subsequent production of undesirable flavors and quality losses. On the other hand, pigments such as chlorophylls are also important contributors to the appearance and health-promoting properties of avocado (Ashton et al., 2006; Lassen, Bacon, & Sutherland, 1944). Nevertheless, the presence of naturally occurring chlorophyll pigments promotes the photooxidation of avocado oil under lighted conditions. Singlet oxygen is produced and reacts with unsaturated fatty acid which forms hydroperoxides. The decomposition of these hydroperoxides initiates a free-radical type of autooxidation inducing color changing (Werman & Neeman, 1986).

Minimal processing techniques, including the addition of preservatives from synthesis sources have been proposed to extend shelf life and marketability of fresh-cut avocados (Dorantes-Alvarez et al., 1998; Elez-Martínez et al., 2005; Guzmán-Gerónimo, López, & Dorantes-Alvarez, 2008; Soliva-Fortuny et al., 2001). As an alternative strategy, emerging non-thermal technologies including Pulsed light (PL) is under study for their great potential in extending shelf life of fresh-cut products without compromising their nutritional value (Aguiló-Aguayo, Charles, Renard, Page, & Carlin, 2013; Charles, Vidal, Olive, Filgueiras, & Sallanon, 2013; Gómez, García-Loredo, et al., 2012; Oms-Oliu, Aguiló-Aguayo, Martín-Belloso, & Soliva-Fortuny, 2010; Ramos-Villarroel, Aron-Maftei, Martín-Belloso, & Soliva-Fortuny, 2012; Ramos-Villarroel, Aron-Maftei, Martín-Belloso, & Soliva-Fortuny, 2014). PL involves

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the use of short-time high-peak pulses of bread-spectrum white light on the surface of either foods or packaging materials. According to Woodling and Moraru (2005), it is the UV portion of the spectrum that plays the main role in microbial inactivation.

The most crucial challenge of PL processing is to optimize the processing conditions to extend shelf-life of fresh-cut products, while assuring appropriate quality. Hence, the present research examines the impact of PL treatments in aspects related to the shelf-life of fresh-cut avocados including microbial growth, quality attributes and oxidative stability of the lipid fraction.

2. Material and methods

2.1. Fresh-cut avocado preparation

Avocados (var. Hass) were purchased unripe at a local market and maintained under controlled conditions at 10 °C until they reached the desired level of ripeness, as defined by Soliva-Fortuny, Elez, Sebastián, and Martín (2000) (Table 1). The whole fruits were rinsed with chlorinated tap water. As well, any surface and tool in contact with the fruit (working area, cutting blades and gloves) were washed and disinfected with a solution of sodium hypochlorite containing 200 ppm of free chlorine (pH 7). Avocados were peeled, the pit was removed and the flesh was cut into pieces of 3.0 cm × 1.5 cm × 1.5 cm. CIELAB values of the fruit flesh were determined with a colorimeter (Konica Minolta Sensing, Inc., Chroma Meter Model CR-400, Osaka, Japan). The firmness was determined using a TA-XT2 texturometer (Stable Micro Systems Ltd., Surrey, England, UK) by measuring the force required for a 4-mm-diameter probe to penetrate to a depth of 10 mm into an avocado piece. Determination of pH (Crison Instruments S.A., Crison 2001 pH-meter, Alella, Barcelona, Spain) and soluble solids content (Atago Company Ltd, Atago RX-1000 refractometer, Atago, Japan) were also carried out.

2.2. PL treatments and packaging

PL treatments were carried out with an automatic laboratory flash lamp system which comprises two xenon lamps individually and symmetrically located above and below the chamber (SteriBeam Systems GmbH, SteriBeam XeMaticA-2L, Kehl, Germany). Six pieces of avocado (approximately 25 g) were placed on a polypropylene trays of 500 m^3 (MCP Performance Plastic Ltd., Kibbutz, Hamaapil, Israel) that allows full transmission of the light spectrum. One tray was treated at a time. The tray was placed in a sample holder at a distance of 5 cm between the flash lamps. The emitted spectrum ranged from 200 to 1100 nm with 15% to 20% of the light in the UV region. The duration of one pulse emitted by each lamp was 0.3 ms with a fluence of 0.4 J/cm^2. The total light energy reaching the sample was calculated according to photodiode readings at the sample holder. Measurements were calibrated with a standard light source and the overall fluence per pulse was estimated following manufacturer's directions. Both avocado sides were simultaneously treated with 9, 15 and 35 pulses, corresponding to fluences of 3.6, 6.0 and 14 J/cm^2 emitted per lamp to each sample side.

Once treated, trays were sealed with a 64 mm-thick polypropylene film with an oxygen permeability of 110 cm^3 m^{-2} day^{-1} bar^{-1} at 23 °C and 0% RH (Tecknopack SRL, Mortara, Italy) using a vacuum compensated packing machine (ILPRA Systems España, S.L., ILPRA Food Pack Basic V/6, Mataró, Spain). The packages were stored for 15 days at 4 ± 1 °C in darkness up to random withdrawal for analysis.

Table 1
Physico-chemical characteristics of fresh Hass avocados before processing.

pH	6.72 ± 0.02
Total acidity (g citric acid/100 g fruit pulp)	0.13 ± 0.01
Soluble solids content (°Brix)	8.56 ± 0.50
Pulp maximum penetration force (N)	0.453 ± 0.012
Skin maximum penetration force (N)	9.0 ± 0.1
Pulp color	
L^*	46.07 ± 0.16
a^*	−19.70 ± 0.38
b^*	30.29 ± 0.44

Results are the mean ± SD of three measurements.

2.3. Microbiological analyses

Total aerobic mesophilic and yeast and mold populations on fresh-cut avocados were evaluated during refrigerated storage. At each sampling time, two replicate packages were withdrawn and their content was homogenized. Portions of 10 g of avocado were crushed in sterile conditions for 2 min with 90 ml of peptone water (0.1 g/100 ml) (Scharlau Chemie, S.A., Barcelona, Spain) with a Stomacher Lab Blender 400 (Seward Medical, London, England). Two trays were taken at each sampling time throughout 15 days of storage and two replicate analyses were performed from each one. Serial dilutions of the obtained homogenates were poured in plate count agar and chloramphenicol glucose agar (Biokar Diagnostics, Beauvais, France) and incubated at 30 ± 1 °C for 72 h and at 25 ± 1 °C for 5 days for mesophilic aerobic bacteria counts (ISO 4833, 1991) and for yeast and mold counts (ISO 7954, 1987), respectively.

2.4. Color evaluation

Color was measured with a colorimeter (Minolta Sensing Inc, Minolta Chroma Meter Model CR-400, Osaka, Japan). The equipment was set up for a D_{65} illuminant and 10° observer angle. Two trays were taken at each sampling time throughout 15 days of storage and triplicate analysis was carried out from each one. CIE L^* (lightness), a^* (red-green) and b^* (yellow-blue) parameters were measured through reflectance values. These values were used to calculate the hue angle (h) (Eq. (1)).

$$h = \arctan\frac{b^*}{a^*} \quad (1)$$

2.5. Chlorophylls extraction and measurement

Chlorophyll extraction was carried out using a modification of the method described by Lancaster, Lister, Reay, and Triggs (1997). Chlorophylls were extracted from a sample of 0.5 g avocado with 5 ml of cold acetone containing 1 g/100 ml of calcium carbonate to prevent degradation. The mixture was homogenized with an Ultra Turrax T25 (IKA® WERKE, Germany) for 30 s at maximum speed and the homogenate was centrifuged at 15,000 × g for 10 min at 4 °C (Beckman Instruments Inc., Centrifuge AVANTI™ J-25, Fullerton, CA, USA). The total volume of the extract was measured and its absorbance was recorded spectrophotometrically at 663 and 645 nm, using a 1 cm path cuvette (Cecil Instruments Ltd., Cecil CE 1010, Cambridge, UK). The concentrations of chlorophylls a and b were calculated from equations (2) and (3), respectively (Maclachlan & Zalik, 1963).

$$\text{Chlorophyl } a = \frac{(12.3\cdot A_{663} - 0.86\cdot A_{645})\cdot V}{1000\cdot d\cdot w} \quad (2)$$

$$\text{Chlorophyl } b = \frac{(19.3\cdot A_{645} - 3.6\cdot A_{663})\cdot V}{1000\cdot d\cdot w} \quad (3)$$