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Impact of pulsed light treatments on antioxidant characteristics and quality attributes of fresh-cut apples

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ABSTRACT

The effects of pulsed light (PL) treatments combined with a quality-stabilizing dip on the quality and antioxidant attributes of fresh-cut 'Golden delicious' apples was studied. Apple wedges were dipped into a solution of 1% *w*/*v* N-acetylcysteine and 0.5% *w*/*v* $CaCl_2$ and flashed with broad-spectrum light with an overall radiant exposure of 4, 8, 12 and 16 J·cm^{-2}. General microbial counts, colour, firmness, phenolic compounds and vitamin C contents were evaluated over 15 days at 5 °C. More pronounced reductions of the naturally-occurring microbiota were observed as the applied PL-dose increased. The quality-stabilizing pre-treatment effectively prevented browning phenomena on the cut-tissue surface. In addition, browning and oxidation were not promoted in PL flashed samples. Indeed, the initial contents in phenolic compounds and vitamin C were even better maintained than in untreated samples. Treatments of 8 and 16 J cm^{-2} were most effective for maintaining the quality and antioxidant characteristics.

Industrial relevance: Pulsed light technology is an emerging technique with good prospects for the decontamination of foods and food contact surfaces. Application of pulse light treatments for increasing safety and extending microbial shelf life of fresh-cut produce seems feasible. However, their effects on the quality and antioxidant characteristics of fruit need to be evaluated for successfully applying the technology at an industrial level.

1. Introduction

Current well-being culture is promoting natural food products as the most desirable items of a healthy diet. Fruit and vegetables are the paradigms within this trend due to their amounts of highly desirable nutrients as well as to their low fat content.

Consequently, food researchers and stakeholders are looking for ways to follow this trend by developing new products such as ready-to-eat fruits, which preserve the fresh-like properties of the raw materials and, at the same time, are convenient and appealing to consumers. As processing operations cause injuries to fruit tissues that result in a reduction of their shelf-life, industry is looking for gentle technological processes that minimize microbial safety threads in processed fruits while keeping under control the typical quality losses of a living product. Chemical compounds such as antioxidants, texture stabilizers, and antimicrobials, either from natural or synthetic origin, have been broadly used for such targets (Martín-Diana et al., 2007; Rojas-Graü, Soliva-Fortuny, & Martín-Belloso, 2008; Soliva-Fortuny, Ricart-Coll, & Martín-Belloso, 2005). On minimally processed fruits and vegetables, these treatments have been applied alone or incorporated into edible coating layers (Raybaudi-Massilia, Mosqueda-Melgar, Soliva-Fortuny, & Martín-Belloso, 2009; Valencia-Chamorro, Palou, del Río, & Pérez-Gago, 2011; Vargas, Pastor, Chiralt, Mc Clements, & González-Martínez, 2008). Their industrial application may be sometimes limited by regulations or, most frequently, by the awareness of consumers to food additives. However, certain antioxidant treatments including dips into ascorbic acid or naturally occurring thiol-compounds are commercially used to delay the development of signs of browning and discoloration on the cut surface of fresh-cut produce. Furthermore, calcium salts have been widely used as firming agents in the fruits and vegetables industry for both whole and fresh-cut commodities (Martín-Diana et al., 2007). On the other hand, calcium treatments have been widely applied in combination with ascorbic acid and thiol-compounds such as cysteine, N-acetylcysteine, and reduced glutathione to prevent enzymatic browning and maintain firmness of fruits (Rojas-Graü, Sobrino-López, Tapia, & Martín-Belloso, 2006; Rojas-Graü et al., 2008; Soliva-Fortuny, Grigelmo-Miguel, Odriozola-Serrano, Gorinstein, & Martín-Belloso, 2001; Soliva-Fortuny, Oms-Oliu, & Martín-Belloso, 2002). Since calcium chloride may impart flavour, the use of other calcium salts such as calcium propionate, lactate, and ascorbate has been recently suggested (Aguayo, Requejo-Jackman, Stanley, & Woolf, 2010; Alandes, Hernando, Quiles, Pérez-Munuera, & Lluch, 2006; Barbagallo, Chisari, & Caputa, 2012; Quiles, Hernando, Pérez-Munuera, & Lluch, 2007).

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An innovative approach for this type of highly valuable products is the use of physical technologies. Pulsed light (PL) is a non-thermal emerging alternative for the superficial decontamination of surfaces by application of light pulses of short duration, on the order of milliseconds and high frequency. The intensity of the light pulses as well as their wide range of wavelengths start a cascade of photo-thermal and photo-chemical processes on the surface tissue of the fruit (Gómez-López, Ragaert, Debevere, & Devlieghere, 2007; Oms-Oliu, Martín-Belloso, & Soliva-Fortuny, 2010b). Previous studies demonstrated the applicability of PL treatments for the decontamination of fresh-cut products such as watermelon, different apple cultivars, avocado, or mushrooms (Gómez, Salvatori, García-Loredo, & Alzamora, 2012; Ignat, Manzocco, Maifreni, Bartolomeoli, & Nicoli, 2014; Oms-Oliu, Aguiló-Aguayo, Martín-Belloso, & Soliva-Fortuny, 2010a; Ramos-Villarroel, Aron-Maftei, Martín-Belloso, & Soliva-Fortuny, 2012; Ramos-Villarroel, Martín-Belloso, & Soliva-Fortuny, 2011). However, it is well known that light can have a negative effect on the quality of the fresh-cut products, leading to the degradation of various compounds, such as those significantly contributing to the antioxidant properties of fruit. Little information about this topic has been published and only a few works have evaluated the effects of PL treatments on antioxidant compounds of whole (Aguiló-Aguayo, Charles, Renard, Page, & Carlin, 2013; Rodov, Vinokur, & Horev, 2012) and fresh-cut (Charles, Vidal, Olive, Filgueiras, & Sallanon, 2013; Oms-Oliu et al., 2010a; Zhan, Li, Hu, Pang, & Fan, 2012) fruit and vegetables. In this context, the present work was aimed to study the effect of different pulsed light doses in combination with the use of a quality-stabilizing solution on different quality aspects of fresh-cut 'Golden delicious' apples with a stress on their antioxidant content throughout storage.

2. Materials and methods

2.1. Processing of fresh-cut apples

'Golden delicious' apples were purchased in a local supplier in Lleida (Spain) at commercial maturity, and stored at 5 ± 1 °C prior to processing. The fruits were washed and sanitized by immersion into a 200 μL L^{-1} sodium hypochlorite solution for 1 min; then rinsed, and dried with paper cloth prior to cutting. Apples were peeled with a sharp stainless-steel knife, cored and cut into 10 wedges with a hand-operated apple corer/slicer. After that, apple pieces were dipped for 1 min into a quality-stabilizing solution containing 1% *w*/*v* N-acetylcysteine and 0.5% *w*/*v* $CaCl_2$ in a solid/liquid ratio of 1:2, as per the commercial practice. Once the excess of solution was blotted off by draining for 5 min, five apple wedges with a weight of approximately 14 g each (ca. 70 g) were placed separately in transparent polypropylene trays which were thermosealed using a packaging machine (ILPRA Food Pack Basic V/G, ILPRA Systems, Vigevano, PV, Italy). The sealing film had 64 μm-thick and an oxygen permeability of 110 cm^3 O_2 m^{-2} bar^{-1} day^{-1} at 23 °C and 0% RH (Tecnopack SRL, Mortara, Italy). The film transparency was more than a 97% to the incident UV-radiation and almost a 100% to the visible radiation, whereas, the packaging transparency was a 85% of the incident energy corresponding to wavelengths between 200 and 320 nm, which is why the fresh-cut apple pieces were exposed to the PL-treatments once inside the package. Untreated apple samples were prepared with and without immersion into the quality-stabilizing solution to be used as a reference. Once processed, fresh-cut apples were immediately stored for 15 days at 5 ± 1 °C in darkness. Twelve replicates of each one of the assayed treatment conditions were prepared to be randomly withdrawn every 3 days for analysis. Fresh tissues were used for microbiological and quality determinations whereas a portion of 25 g was immediately freeze-dried and stored at −40 °C until extraction and determination of antioxidant compounds.

2.2. Pulsed light treatments

Pulsed light (PL) treatments were carried out using a pulsed UV system Model XeMaticA-2 L (360° sample illumination) (SteriBeam Systems GmbH, Kehl, Germany) with two air cooled Xenon lamps situated 8.5 cm far above and below a quartz sample shelf (Fig. 1). The emitted spectrum wavelengths ranged from 180 to 1100 nm with 15–20% of the light in the UV region. Each pulse lasted 0.3 ms and the energy deposition per pulse delivered by each lamp at the sample level was 0.4 J·cm^{-2} per pulse. Each package was individually treated with 10, 20, 30 or 40 light flashes, corresponding to doses of 4, 8, 12, and 16 J·cm^{-2} per side, respectively. PL-doses were obtained by measuring the amount of energy received by a photodiode detector placed at the sample holder. The photodiode was connected to an oscilloscope and the recorded signal was transformed into radiance values using a calibration with a standard light source as per the instruction of the manufacturer. In addition, a Makrolon® filter was used to evaluate the amount of radiation in the UV range. Broad-range and UV-range radiations emitted by top and bottom lamps were not much differentially blocked by the packaging materials. Photodiode readings revealed differences of less than 5% in the fluences at the sample level after passing through the package foils. In concomitance with the dose increase, the temperature of fruit surface may gradually rise on the treated surfaces as well as inside the treatment chamber. Just after the highest PL-treatment (16 J·cm^{-2}), the highest temperature recording at the sample shelf level was 42.4 ± 1.0 °C.

2.3. Microbiological quality evaluation

Approximately 10 g of fresh-cut apple wedges were homogenized for 1 min with 90 mL of saline peptone water (0.1% *w*/*v* peptone + 0.85% *w*/*v* NaCl) with a stomacher blender under sterile conditions (IUL Instruments, Barcelona, Spain). Serial dilutions of the homogenates were poured in plate count agar (PCA) at 30 ± 1 °C for 72 ± 3 h and 7 ± 1 °C for 7 days for mesophilic and psychrophilic aerobic bacteria counts, respectively (ISO 4833, 1991) and chloramphenicol glucose agar (CGA) at 25 ± 1 °C for 5 days for molds and yeasts counts (ISO 7954, 1988). Peptone and agar media were purchased from Biokar Diagnostics (Beauvais, France). Two packages were taken at each sampling time to perform the analysis and two replicate counts were carried out for each one. Results were expressed as colony forming units (CFU) per gram of fresh apple piece.

2.4. Colour determination

Cut apple surface colour values were directly measured with a colorimeter (ChromaMeter Model CR-400, Konica Minolta Sensing Inc.,

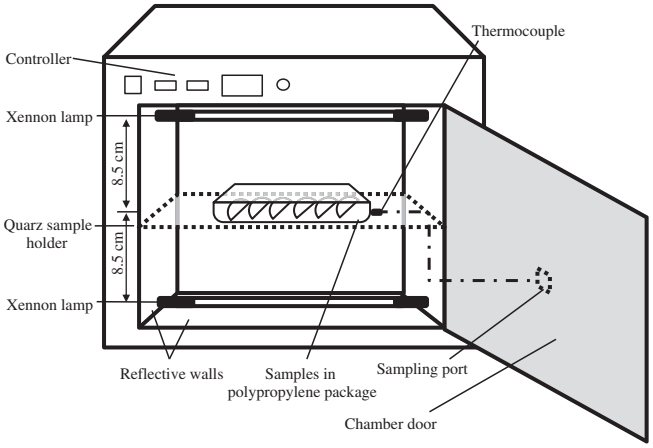

Fig. 1. Schematics of the PL-treatment chamber.

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