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Combined effect of pulsed light, edible coating and malic acid dipping to improve fresh-cut mango safety and quality

B. Salinas-Roca [a], R. Soliva-Fortuny [a], J. Welti-Chanes [b], O. Martín-Belloso [a, b, *]

[a] University of Lleida, Department of Food Technology – Agrotecnio Center, Rovira Roure 191, 25198 Lleida, Spain
[b] Centro de Biotecnología FEMSA, Escuela de Ingeniería y Ciencias, Tecnológico de Monterrey, Av. Eugenio Garza Sada 2501 Sur, Col. Tecnológico, 64849 Monterrey, Mexico

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ABSTRACT

The impact of pulsed light (PL), alginate coating (ALC) and malic acid dipping (MA) treatments on quality and safety aspects of fresh-cut mango was studied. Fresh-cut mangoes were inoculated with *L. innocua* and then subjected to PL (20 pulses at fluence of 0.4 J·cm^{-2}/pulse), ALC (2 %) or MA (2 %) treatments. Moreover, different combinations of PL, ALC and MA were assayed to evaluate possible synergisms among treatments. Microbial stability and quality parameters (colour, pH, soluble solids and firmness) of fresh-cut mango were examined throughout 14 days of storage at 4 °C.

Results show that MA-PL and PL-ALC-MA treatments additively reduced *L. innocua* counts by 4.5 and 3.9 logs, respectively. Microbial population in fresh-cut mango remained below 6 log CFU/g over 14 days. Differences between firmness values of untreated and treated fresh-cut mangoes were evident throughout storage. Namely, firmness of alginate-coated slices sharply increased and progressively decreased over storage. Colour parameters and total soluble solids content decreased in all treated mango slices throughout 14 days, while pH was kept similar to that of the fresh tissue. An optimal combination of different treatments enables to ensure safety of fresh-cut mango with minimal quality deterioration throughout storage.

1. Introduction

The growing demand for ready-to-eat fruits and vegetables has led to an increasing interest in the study of methods that enhance their safety while preserving freshness. Although fruits do not generally pose a safety hazard, peeling and cutting operations make fresh-cut fruits more susceptible to microbial attack. *Listeria* sp can be a hazardous contaminant of fresh-cut fruits as it is able to survive in a wide range of pH and temperature conditions. In fruits of low acidity, in which mango is included, *Listeria* sp may also find the conditions to survive and multiply (Penteado, de Castro, & Rezende, 2014). Among fresh-cut melon, apple and pineapple are the most commonly consumed and studied; however the demand for other fruits such as mango is continuously growing (Siddiq, Sogi, & Dolan, 2013). Mango (*Mangifera indica L.*) is one of the most harvested tropical fruits (FAO, 2012). It is widely demanded for its yellow colour, fleshy texture and unique flavour. Freshness and appearance are the primary criteria determining consumer satisfaction. Produce safety is also critical to maintain consumer confidence. Therefore, developing adequate treatments to obtain fresh-cut mango could help to promote its consumption and enable industry to satisfy the market trends.

Recent research in preservation methods for fresh-cut fruits has focused on assuring safety and maintaining original characteristics of fruit, while avoiding the undesired effects caused by handling and processing (Caminiti et al., 2011; Moody, Marx, Swanson, & Bermúdez-Aguirre, 2014; Proctor, 2010). Pulsed light (PL) treatments are being studied as a feasible alternative to conventional preservative processes (Oms-Oliu, Martín-Belloso, & Soliva-Fortuny, 2008). This technology involves the application of very short high-intensity pulses of broad spectrum light: (180–1100 nm). The composition of the spectrum and the energy density has been shown to play an important role in microbial cell death by PL (Keklik, Demirci, Puri, & Heinemann, 2012; Ramos-Villarroel, Martín-Belloso, & Soliva-Fortuny, 2011). Different studies have proposed the use of PL treatments for the decontamination of fresh-cut fruits; however, applications for fresh-cut tropical fruits are scarce. As far as we know, literature offers only

* Corresponding author. University of Lleida, Department of Food Technology – Agrotecnio Center, Rovira Roure 191, 25198 Lleida, Spain.
E-mail address: omartin@tecal.udl.cat (O. Martín-Belloso).

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a prospective study regarding the application of PL for the decontamination of fresh-cut mango (Charles, Vidal, Olive, Filgueiras, & Sallanon, 2013). On the other hand, edible coatings based on polysaccharides such as sodium alginate have been proposed for extending the shelf-life of fresh-cut fruits (Rojas-Graü, Tapia, Rodríguez, Carmona, & Martin-Belloso, 2007). These coatings are commonly formed as a thin layer on the cut surface of fruits, acting as a barrier against gas exchange and transpiration. Edible coatings enable to retard the physiological response to mechanical stress and other physical disorders leading to moisture and solutes migration, gas exchange, respiration and increased oxidative phenomena that have a deleterious impact on the product quality (Oms-Oliu et al., 2010; Raybaudi-Massilia, Mosqueda-Melgar, & Tapia, 2010). However, their effects in preventing microbial inactivation are scarce (Raybaudi-Massilia, Mosqueda-Melgar, & Martín-Belloso, 2008). The use of organic acids is another strategy which could be used to ensure safety of fresh-cut fruits. Malic acid dips have been shown to enable a decrease in microbial loads, thus ensuring safety and extending quality of fresh-cut produce over storage (Gómez et al., 2012; Raso & Barbosa-Cánovas, 2003; Rojas-Graü, Raybaudi-Massilia, et al., 2007; Rojas-Graü, Tapia, et al., 2007; Tapia et al., 2007; Valencia-Chamorro, Palou, Del Río, & Pérez-Gago, 2011). Their antimicrobial activity could be attributed to the reduction of the medium pH, decrease of the intracellular pH by ionization of undissociated acid molecules.

As these strategies do not individually succeed in guaranteeing safety and quality maintenance of fresh-cut fruits, a combined methods approach stands as a good alternative to achieve this goal. Hence, the aim of the present work was to assess the effectiveness of combining PL, alginate coating and malic acid on the reduction of *Listeria innocua* population as well as to evaluate microbial growth and physicochemical parameters (pH, soluble solids, colour and firmness) of mango slices over refrigerated storage.

2. Materials and methods

2.1. Mango slices preparation

'Tommy Atkins' mangoes were purchased from a local market (Lleida, Spain) at commercial maturity. Mango pH (3.46 ± 0.01) (Crison 2001 pH-meter; Crison Instruments S.A; Barcelona, Spain), total soluble solids (13.9 ± 0.2 °Brix) (Atago RX-1000 refractometer, Atago Company Ltd; Japan) and firmness (5.7 ± 0.7 N·s) (Texture Analyzer TA-XT2 Stable Micro Systems Ltd., Surrey, England, UK) of the fruit flesh were determined before processing. Whole mangoes were washed with an aqueous solution of sodium hypochlorite (300 μL/L) and then peeled and cut to obtain 5 mm-thick slices. Sliced mangoes were inoculated and/or subjected to the different treatments, as described in the following sections. Once treated, slices (35 ± 1 g) were placed into transparent polypropylene trays and stored (4 ± 1 °C) until analysis at days 0, 3, 7, 10 and 14.

2.2. Listeria innocua culture and inoculation

L. innocua IPL 1.17 (Institute Pasteur de Lille; Lille, France), as a surrogate of the pathogenic *Listeria monocytogenes*, were provided from the culture collections of the Department of Food Technology (University of Lleida, Spain). Stock culture of *L. innocua* was grown in tryptone soy broth (TSB) with 0.6% yeast extract (Bioakar Diagnostic; Beauvais, France) and incubated at 35 °C with continuous agitation at 200 rpm for 15 h to obtain cells in stationary growth phase (10^8–10^9 CFU/mL). Mango slices (35 g) were inoculated by spreading 100 μL of *L. innocua* stock cultures over the entire upper surface with a sterile micropipette before treatment and packaging (Ramos-Villarroel et al., 2011).

2.3. Pulsed light treatment

Pulsed light (PL) treatments were carried out with a XeMaticA-2L System (SteriBeam Systems GmbH, Germany). The experiments were performed at a charging voltage of 2.5 kV. The system is equipped with a lamp situated 8.5 cm above the sample holder. The lamp delivered pulses of 0.3 ms with an overall radiant fluence of 0.4·J cm^{-2} at the sample level. The total light energy was measured according to the calibration of the equipment with a standard light source estimated by photodiode readings and manufacturer's directions. The emitted spectrum ranged from 180 to 1100 nm. To evaluate the effect of the wavelength of PL on the inactivation of *L. innocua*, two types of UV filters were used: a 2 mm-thick Pyrex glass filter that cuts off wavelengths below 305 nm hence allowing to pass some UVB, all UVA, visible light (V) and infrared (IR) wavelengths (89% of the emitted energy); and Makrolon polycarbonate plastic filter that cuts all light below 400 nm, thus allowing only V and IR light to pass through (83% of the emitted energy). In addition, treatments with increasing number of pulses (0, 10, 15, 20, 25, and 30) were assayed in order to evaluate the inactivation of *L. innocua* as affected by PL.

2.4. Alginate coating

Film-forming solutions were prepared by dissolving 20 g of alginate coating (ALC) (FMC Biopolymer Ladybum Works, USA) into 1000 mL of distilled water and homogenised with an Ultra Turrax T25 (IKA WERKE, Germany). Calcium chloride (20 g) was dissolved into 1000 mL of distilled water to be used as a crosslinking agent (Sigma–Aldrich Chemic. Steinhein, Germany). Mango slices were dipped into the sodium alginate solution (2% w/v) during 2 min and the excess was removed thereafter. A second dipping in calcium chloride (2% w/v) solution was performed for ALC-coated mango slices.

2.5. Malic acid solution

DL-Malic acid (20 g) (MA) (Fluka; Steinhein, Germany) was dissolved by stirring into 1000 mL of distilled water. Mango slices were dipped into MA solution during 2 min. It must be noted that MA was incorporated to the calcium chloride solution when combined with the edible coating.

2.6. Combined treatments

Different combinations of PL (20 pulses of broad-spectrum light), ALC (2 % w/v) and MA (2 %) were evaluated to elucidate possible synergistic, additive or antagonist effects. The evaluated treatments were: ALC followed by PL (ALC-PL), MA followed by PL (MA-PL), ALC followed by MA (ALC-MA), PL followed by ALC and MA (PL-ALC-MA) and ALC followed by MA and PL (ALC-MA-PL). Untreated mango slices dipped in distilled water were considered as a control reference treatment (C).

2.7. Microbiological analyses

Sliced mangoes (10 g) were placed into sterile plastic bags with 90 mL of saline peptone water (Bioakar Diagnostic; Beauvais, France) and homogenized for 1 min in a stomacher blender (IUL Instruments, Barcelona, Spain) for microbial analyses. Serial dilutions were made and 100 μL were placed in Palcam agar plates (Bioakar Diagnostic; Beauvais, France) and spread with a Drigalsky handle. The evaluation was made by duplicate for each dilution and the plates were incubated for 48 h at 37 °C. Microbial population was evaluated and the results expressed as $\log_{10}$ CFU/g.