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The influence of *Opuntia ficus-indica* mucilage edible coating on the quality of 'Hayward' kiwifruit slices

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ABSTRACT

The aim of this work was to study the effect of mucilage edible coating extracted from *Opuntia ficus-indica* (OFI) on the quality and shelf life maintenance of packaged kiwifruit slices. OFI mucilage alone or added with TWEEN® 20 were applied on kiwifruit fresh cut surfaces. After treatments, kiwifruit samples were stored under passive atmosphere at 5 ± 1 °C for 3, 5, 7 and 12 days. At each storage period, visual quality and flavor score, pectin content, ascorbic acid and the microbiological characteristics were measured together with CO_2 and O_2 content in the packages. Kiwifruit slices coated only with mucilage or with mucilage plus Tween 20, showed a significant higher firmness and a lower weight loss than untreated slices, until 5 d of shelf life. No further differences in weight loss occurred after 7 d of shelf life, while slices treated only with mucilage retained the highest firmness until the end of the shelf life period (12 d). OFI mucilage alone had significant beneficial effects on the visual and flavor score of the kiwifruit slices, throughout the shelf life period. The treatment with Tween 20 did not affect the flavor of the kiwifruit slices, compared with untreated fruit. Although mucilage and partly tween 20 addition increased microbial growth, especially of yeasts, their levels were still below the threshold for yeast spoilage at the end of the monitoring period. Hence, the results showed that mucilage coating applied to kiwifruit minimally processed fruit improved the quality of stored fresh-cut kiwifruits.

1. Introduction

The wide success of kiwifruit (*Actinidia deliciosa*) is largely due to the bright color of the flesh that, together with its flavor and high nutraceutical value (high vitamin C content), represents the most important fruit attributes. Indeed, kiwifruit slices are largely used in fruit salads or in confectionery where they are the only green-fleshed fruit used. However, peeling and slicing involved in minimal processing can cause physical damage and increase ethylene production and respiration of kiwifruit. Furthermore, the disruption of the fruit cells caused by the cut, frees the cellular content and promotes the microbial development (Garcia and Barrett, 2002). These phenomena might result in flesh softening and a shorted shelf life of minimally processed kiwifruits (Agar et al., 1999).

Refrigeration (2 °C and >90% RH) associated with $CaCl_2$ or calcium lactate treatment may prolong the shelf life of minimally processed kiwifruit slices up to 9–12 d (Agar et al., 1999) while the use of edible coating based on *Aloe vera* combined with packaging under passive modified atmosphere packaging (MAP) and low temperature (2 ± 1 °C) reduces fruit respiration rates and microbial spoilage of kiwifruit, during 7 d of storage (Benitez et al., 2013). Active coatings under passive MAP also inhibit microbial activity and reduce respiration, while the combination of MAP and active alginate-based coatings delaye quality loss and microbial spoilage of kiwifruit minimally processed slices (Mastromatteo et al., 2011). As a matter of fact, the use of edible coatings is growing, due to their multiple uses for extending fruit shelf life and also as carriers for several food additives (Mastromatteo et al., 2011). Most of the edible coatings are based on carbohydrates, proteins or lipids which can be combined (Oms-Oliu et al., 2008; Valero et al., 2013), such as casein (Ponce et al., 2008) and its derivatives (Fabra et al., 2009), guar gum, cellulose ethyl (Shrestha et al., 2003), gelatin supplemented with glycerol, sucrose and sorbitol as plasticizers (Arvanitoyannis et al., 1997; Sobral et al., 2001), pectin (Maftoonazad et al., 2007), cassava starch (Kechichian et al., 2010), wheat gluten (Tanada-Palmu and Grosso, 2005) and mixtures of sodium alginate and pectin, with the addition of $CaCl_2$ (Da Silva et al., 2009). The mucilage obtained from cladodes of cactus pear (*Opuntia ficus-indica*) has a highly branched complex polymeric structure of carbohydrate nature, (Medina-Torres et al., 2000;

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Matsuhiro et al., 2006) and contains varying proportions of L-arabinose, D-galactose, L-rhamnose and D-xylose (Sáenz et al., 1992; Sepùlveda et al., 2007; Goycoolea and Cárdenas, 2004). The rheological characteristics of *O. ficus-indica* mucilage makes it interesting for the production of edible coatings with a high nutraceutical value. The mucilage from cladodes of *O. ficus-indica* forms an edible coating on the fruit surface that makes the treated product shiny. So far, this mucilage has had several applications in fruit preservation. A combination of *O. ficus-indica* mucilage with citric acid and sodium bisulfite at high concentrations decreases browning of banana (*Musa cavendish*) slices during drying (Aquino et al., 2009). Treatment with *O. ficus-indica* mucilage applied on fresh strawberries reduces fruit weight, color and firmness loss, fruit respiration rate, and fungal infection (Del-Valle et al., 2005). However, to the best of our knowledge, this polymer has been never applied on minimally processed fruit. The efficacy of two different *O. ficus-indica* mucilage-based coating formulations to prolong the shelf life of kiwifruit slices was evaluated. To assess the influence of the treatments, weight loss, softening, sensory quality and microbial load of kiwi fruit were monitored during the storage.

2. Materials and methods

2.1. Samples preparation

'Hayward' kiwifruit (*Actinidia deliciosa*) were purchased from a retail market (Simply, Palermo, Italy). Fruit were uniform in terms of fresh weight (98 ± 4.8 g), total soluble solid content (13.3 ± 1.5%) and firmness (30.5 ± 3.5 N), analyzed on a sample of 30 fruit. Kiwifruit were stored at 1 ± 0.5 °C (RH = 85%) for 24 h. After storage, fruit were dipped in chlorinated water (100 mL^{-1} of free chlorine) for 6 min. Damaged fruits (bruised or showing other physical decays) were removed, and a total of 300 fruits were processed.

Cactus pear (*O. ficus-indica,* (L.) Mill.) cladodes were cut and cubed (2 cm^3). To extract the mucilage, cladodes were crushed in a blender (Moulinex) with rotating knifes, homogenized with distilled water in the ratio 1:1.5 (w/v) at 20 °C. The solution was maintained at 40 °C for 90 min and centrifuged (model CS6R) at 1450*g* × 20 min. The supernatant was boiled to half the initial volume and ethanol (99% v/v) was added in the ratio 1:2 (Sáenz et al., 1992). Afterwards, the solution was stored at 4 ± 1.0 °C for 48 h to allow a better aggregation of the mucilage. The last phase involved the elimination of the supernatant and soaking of the pure mucilage.

Kiwifruits were peeled using an automatic machine (Agrimat, Maxistreap, Italy) and cut into slices with a semiautomatic machine (Sgorbati, Italy). Slices were 2.2 ± 0.2 cm thick and 5.4 ± 1.2 cm width; L* was 48± 2.1, a* was −8.2 ± 1.2 and b* was 25.4 ± 3; total solid soluble content (TSS) was 13.1 ± 2.5% and titratable acidity (TA) was 1.4 ± 0.3%. Fresh-cut slices were dipped in the (OFI) coating solution for 60 s; the excess coating was drained and the coated slices were dried with a forced-air dryer (20 °C) for 10 min.

The coating treatments consisted of: a) 30 g of pure mucilage extract, 500 mL distilled water and 50 mL glycerol as a plasticizer (MC); b) 30 g of mucilage extract, 500 mL distilled water, 50 mL glycerol added with 2 mL Tween 20 (TW). The control treatment (CTR) wereslices dipped in distilled water. About 95 ± 1.1 g of kiwifruit slices were packed in polyethylene terephthalate (PET) packages and sealed with a composite film (PP-PET), 64 μm, O_2 permeability = 5.30×10^{-8} μL m^{-2} s^{-1} Pa^{-1}. Packages were stored at 5 ± 0.5 °C and 90% relative humidity (RH) for 12 d. Chemical, physical and microbiological parameters were analyzed, at the beginning of the experiment (after coating/dipping = day 0) and at 3, 5, 7, and 12 d after storage, on six slices per replicate for treatment (3 treatments combinations × 5 time of storage × 6 replicates = 90 box).

2.2. Chemical and physical analysis

2.2.1. Firmness

Firmness was evaluated with a puncture test on kiwifruit slices flesh using a TA-XT Plus texture analyzer (Stable Micro Systems) equipped with a 50 N load cell of. Firmness measurements were taken as the median force value obtained during the test with a stainless steel probe with 4 mm diameter penetrating the fruit 4 mm, at 1 mm/s. Average values were calculated from the results of at least 6 measurements in different slices for each sample. Measures were taken in fruit outer pericarp (green flesh) where the fast rate of softening compromises fruit quality.

2.2.2. Weight loss

Weight of individual bags was recorded immediately after the treatment (day 0) and at the different sampling times (3, 5, 7, and 12 days during storage). Weight loss was expressed as the percentage reduction with respect to initial time, using the following equation:

% Weight loss: [(Initial fruit bag weight − Final fruit bag weight) × 100]/Initial fruit bag weight

2.2.3. Total soluble solids content and titratable acidity

The concentration of total soluble solids (TSS expressed as%) determined from the juice of four slices from each tray using a digital refractometer (model PR-101, Atago, Co., Tokyo, Japan) at 20 °C.

Titratable acidity (expressed as% citric acid) was determined by titration of 10 mL of juice with 0.1 M NaOH to an endpoint of pH 8.1.

2.2.4. Sensory evaluation

2.2.4.1. Visual appearance score. To measure the effect of cold storage on kiwifruit sensory traits at each storage time (0, 3, 5, 7 and 12 d), six slices, used as single replicates for each treatment (MC, TW and CTR), were scored by each of a six judges trained panel that generated a list of descriptors in a few preliminary meetings. Visual appearance score resulted from the medium value of color, visible structural integrity and visual appearance (Allegra et al., 2015a). The different descriptors were quantified using a subjective 5–1 rating scale with 5 = very good, 4 = good, 3 = sufficient (limit of marketability), 2 = poor (limit of usability) and 1 = very poor (inedible).

2.2.4.2. Flavor score. To measure the effect of cold storage on slices fruit flavor traits at each storage time, six slices, used as single replicates for treatment (MC, TW and CTR), were scored by six trained judges, using a subjective 5–1 rating scale with 5 = very high, 4 = high, 3 = sufficient (limit of marketability), 2 = low and 1 = none.

2.2.5. Package O_2 and CO_2 analysis

CO_2 and O_2 levels (kPa) were measured on each package at the beginning of each experiment and after 3, 5, 7, 12 days of storage, using a PBI Dansensor Checkpoint O_2 and CO_2 analyzer (Topac, Hingham, MS, USA) with zirconium and infrared detectors, respectively.

2.2.6. Ascorbic acid

Ascorbic acid concentration was determined according to Rapisarda and Intelisano (1996) by high performance liquid