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Raspberry fresh fruit quality as affected by pectin- and alginate-based edible coatings enriched with essential oils

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ABSTRACT

The effects of optimized edible coatings based on sodium alginate (AL) or pectin (PE) with the essential oil constituent additives, citral (Cit) and eugenol (Eug), were studied on fresh raspberries quality during storage at 0.5 °C. Several formulations of edible coatings were used as treatments: AL and PE were tested at 1% and 2% (w/v) with Cit and Eug at minimum inhibitory concentrations (MIC) (0.15 and 0.1%, respectively), at double the MIC concentration and their combination at MIC. Raspberries were immersed in each solution (treatment) for 2 min, and then cooled at 0.5 °C. On days 0, 7, and 14th, samples were removed and used for the following physicochemical and biochemical analysis: color CIE (L^*, °hue), firmness, soluble solids concentration (SSC), weight loss, trolox equivalent antioxidant capacity (TEAC), microbial growth, and taste panels. Color parameter L^* and TEAC were not significantly affected by the coatings. Cit at higher concentrations reduced °hue and firmness and increased weight loss. The SSC decreased mainly in controls. Edible coatings enriched with Cit and Eug were effective at reducing microbial spoilage. Taste panels showed lower scores in Cit 0.3% treatments and raspberries were considered not acceptable after 14 days storage. No significant differences were observed between PE and AL. Raspberries immersed in water (control + water) performed worse than fruit stored without any immersion or wash (control). With the results of the physicochemical and biochemical parameters measured, 3 similar treatment groups were formed by the principal component analysis (PCA) and hierarchical cluster analysis (HCA), either for AL or PE coatings. The group which had better performance was selected for AL- and PE-based edible coatings. From each group the two best edible coating formulations with the higher sensory evaluation were selected. Those confirmed that raspberries were better preserved in terms of general sensory attributes with coatings of AL 2% + Cit 0.15% and AL 2% + Eug 0.1%, and with PE 1% + Eug 0.1% followed by PE 1% + Cit 0.15% + Eug 0.1%.

1. Introduction

Red raspberries (*Rubus idaeus* L.) are of high economic importance and widely consumed in fresh, frozen, or in processed forms, such as jams and juices. In addition to their attractive color and flavor, raspberries contain a unique phytochemical profile. Specifically they are rich in ellagitannins and anthocyanins, which distinguishes them from other berries and fruits (Rao and Snyder, 2010).

The postharvest life of berries is generally determined by their susceptibility to water loss, softening, mechanical injuries, and especially to the presence of postharvest pathogens (Tezotto-Uliana et al., 2014). Various studies have proposed strategies to control postharvest pathogens, while preserving the quality of this fruit, such as modified atmospheres, forced-air cooling or other cooling processes, heat shock, osmotic treatments, irradiation, and edible coatings (Velickova et al., 2013).

Edible coatings have been of increasing interest because of their capacity to reduce respiration and transpiration rates, while increase storage periods and the retention of berry firmness (Azevedo et al., 2014; Tezotto-Uliana et al., 2014; Velickova et al., 2013; Vu et al., 2011). Edible coatings also provide good mechanical properties, are non-toxic and non-polluting, and can be applied at low cost.

The incorporation of antimicrobial agents, such as essential oils or their compounds, into edible coatings can enhance the functionality of coatings in protecting food from microbial spoilage and thus extending their postharvest life and quality (Antunes et al.,

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2012). Because the chemical composition of plant-derived products, such as essential oils, are highly variable with season and cultural practices, the utilization of sole compounds instead of naturally produced essential oil mixtures is a better approach to obtain an edible coating with constant characteristics (Azevedo et al., 2014; Miguel, 2010).

Eugenol, the main constituent of the essential oil isolated from clove flower buds [*Syzygium aromaticum* (L.) (Merrill & Perry)] has antioxidant, antimicrobial, antinociceptive, and antiviral activities (Cortés-Rojas et al., 2014). Citral is a mixture of two stereoisomeric monoterpenes aldehydes: the *E*-isomer specifically referred as geranial or citral A (40–62%), and the Z-isomer (25–38%) known as neral or citral B. This isomer mixture can be isolated from the essential oil of *Cymbopogon citratus* (lemongrass) and *Litsea cubeba.* Citral is used in traditional medicine as antispasmodic, analgesic, anti-inflammatory, antipyretic, diuretic, and sedative. Citral also possesses antimicrobial activity and insecticidal property (Maswal and Dar, 2014).

Polysaccharide edible coatings have good coating-forming and low oxygen permeability properties, as well as, the capacity to decrease the respiration rate of fresh-cut products (Campos et al., 2011). Sodium alginate (AL) is a polysaccharide derived from brown sea algae (Phaeophyceae) and is a linear unbranched polymer containing mannuronic and guluronic acids (Rojas-Graü et al., 2008). Pectin (PE) based edible coatings are extracted from apple waste or citrus peel and are homopolymeric linear chain of galacturonic acid units (Oms-Oliu et al., 2008).

The objective of this research was to study the effects of edible coatings based on AL or PE with Cit and/or Eug incorporated, on the storage ability and fruit quality of fresh red raspberries. Knowledge of how essential oils influence storage ability could prolong the postharvest lifespan of fresh raspberry, which could increase the market window and have positive economic implications.

2. Materials and methods

2.1. Edible coatings formulations

Pectin (PE) and sodium alginate (AL) (Sigma–Aldrich Chemic, Steinhein, Germany) were the biopolymers used for coating formulations and calcium chloride (Sigma–Aldrich Chemic, Steinhein, Germany) was used to induce cross linking reaction (Olivas et al., 2007). The essential oils components, citral (Cit) and eugenol (Eug), were purchased from Sigma–Aldrich Chemic, Steinhein, Germany.

The coating forming solutions based on AL or PE were formulated as described by Rojas-Graü et al. (2007). Ascorbic acid (Scharlau, Barcelona, Spain) at 1% (w/v) was added as anti-browning agent in the edible coating solutions according to previous work (Robles-Sánchez et al., 2009).

The treatments were control (non-treated fruit), control + water (fruit immersed in distilled water for the same time as edible coatings) and edible coatings formulations as described in Table 1.

Concentrations of Cit and Eug were the minimum inhibitory concentrations (MIC) and double MIC determined in a previous work (Guerreiro et al., 2015).

The raspberries (*Rubus idaeus* L.) were from the group of Driscoll's cultivars and were purchased from the local market within 4 h after harvest and immediately transported to the postharvest laboratory at the University of Algarve, where they were selected for the experiments. The experiments were performed within 6 h postharvest at room temperature of 18 °C.

In each treatment, raspberries were first hand-immersed into the edible coating solution for 2 min. Excess of coating material was allowed to drip off for 30 s before the berries were immersed for a second time in the calcium chloride solution for 1 min. After dripping dry for 30 s again, 8 fruits per replication were placed in polypropylene plastic, clamshell type, containers (8 × 10 × 4 cm), perforated in the cover, and stored at 0.5 °C until analysis. On days 0, 7, and 14th, three containers per treatment were taken to perform the analyses. Experiments were repeated twice.

Table 1
Table of coating formulations, using alginate and pectin.

Alginate (AL)	Pectin (PE)
AL 1% (10 g L^{-1})	PE 1% (10 g L^{-1})
AL 1% + Cit 0.15% (Cit 1.5 g L^{-1})	PE 1% + Cit 0.15% (Cit 1.5 g L^{-1})
AL 1% + Cit 0.3% (Cit 3.0 g L^{-1})	PE 1% + Cit 0.3% (Cit 3.0 g L^{-1})
AL 1% + Eug 0.1% (Eug 1.0 g L^{-1})	PE 1% + Eug 0.1% (Eug 1.0 g L^{-1})
AL 1% + Eug 0.2% (Eug 2.0 g L^{-1})	PE 1% + Eug 0.2% (Eug 2.0 g L^{-1})
AL 1% + Cit 0.15% + Eug 0.1%	PE 1% + Cit 0.15% + Eug 0.1%
AL 2% (20 g L^{-1})	PE 2% (20 g L^{-1})
AL 2% + Cit 0.15%	PE 2% + Cit 0.15%
AL 2% + Cit 0.3%	PE 2% + Cit 0.3%
AL 2% + Eug 0.1%	PE 2% + Eug 0.1%
AL 2% + Eug 0.2%	PE 2% + Eug 0.2%
AL 2% + Cit 0.15% + Eug 0.1%	PE 2% + Cit 0.15% + Eug 0.1%

2.2. Determination of qualitative parameters

The color of the raspberries was measured using a Minolta Chroma meter CR-300 (EC Minolta, Japan) using the CIE (L^*, a^*, b^*) scale. Before measuring, the colorimeter was calibrated with a white standard calibration plate. Hue was calculated as h° = arctan (b^*/a^*) (McGuire, 1992). The firmness of the fruits was determined by puncture with a Chatillon TCD200 and Digital Force Gauge DFIS 50 (Jonh Chatillon & Sons, Inc., USA) using a piston cylinder of 4 mm diameter at a depth of 7 mm. A digital refractometer (PR1 ATAGO CoLTD., Japan), was used for the determination of °Brix/soluble solids concentration (SSC) through analysis of the raspberry juice. Weight loss was expressed as the percentage of the initial weight.

2.3. Trolox equivalent antioxidant activity (TEAC)

TEAC was measured as the preformed radical monocation of 2,2′-azinobis-(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) by the modified method of Re et al. (1999). For the assay, 10 μL of the juice was added to 990 μL of ABTS radical cation solution. The absorbance was monitored spectrophotometrically at 734 nm till stabilization, after 6 min (Shimadzu spectrophotometer 160-UV, Tokyo, Japan). The antioxidant activity of each sample was calculated using the following equation: scavenging effect % (SE %) = $(1 - A_s/A_0) \times 100$, where A_0 stands for the absorbance of the control at time 0 and A_s for the absorbance in the presence of the sample after 6 min. The values were compared with the curve for several Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid) concentrations and expressed as mm Trolox equivalent antioxidant capacity.

2.4. Microbial counts

The microbiological parameters that were determined included counts of aerobic mesophilic and psychrophilic bacteria and molds and yeasts. The counts of aerobic mesophilic and psychrophilic microorganisms were done according to the Portuguese NP-3788 standard (2002) using the Plate Count Agar medium (Biokar, Paris, France). The count of molds and yeasts was performed according to ISO 21527-2 (2008) using Dicloran Rose-Bengal Cloranfenicol Agar (Biokar, Paris, France). Ten gram of each sample were transferred to 90 mL of peptone water (Oxoid) and homogenized at their designated sampling times. The incubation conditions for yeasts and molds was 25 ± 1 °C during 48–72 h, 30 ± 1 °C for 24–72 h for aerobic mesophilic bacteria, and 6.5 ± 1 °C during 5–10 days for