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Aloe vera as an alternative to traditional edible coatings used in fresh-cut fruits: A case of study with kiwifruit slices

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In this work, a comparative study between Aloe vera, chitosan (formulated with acetic (-AC) or citric acid (-C)) and sodium alginate edible coatings was conducted to evaluate the effects on the quality and shelf life of minimally processed kiwifruit. The pH, soluble solids content, titratable acidity, ascorbic acid, color, texture properties, gas concentrations, pectin content, microbial load and sensory quality of the fruit were analyzed during 12 days at 4 ± 1 °C. Chitosan-AC and alginate based coatings act as a gas barrier, although after eight days of storage, a sharp rise in CO_2 production was detected for the alginate and chitosan-C coatings. Aloe vera coating maintained the firmness of the fruit, prevented the ascorbic acid losses and yellowing due to ripening. Aloe vera and chitosan-AC reduced microbial proliferation; however chitosan-AC coated slices were not accepted by the sensory panelists. In contrast, fruit treated with an alginate based coating had higher microorganism counts than the control samples. The sensory panel preferred the kiwifruit slices treated with Aloe vera or chitosan-C coatings compared to the other coatings. Our study indicates that Aloe vera was the best coating to both extend the postharvest shelf life and maintain the sensory properties of the product trough the storage period.

1. Introduction

Fresh-cut fruit is expected to maintain fresh-like quality over the course of its shelf life. However, it is well known that peeling and slicing inflicts serious damage to vegetable tissues. The disassembly events of cell components induce biochemical reactions related to changes in color (browning and chlorophyll degradation), texture loss, vitamin oxidation and/or accelerated metabolism. Additionally, fruit juice leakage stimulates microbial growth, which may lead to a foodborne hazard (Rico, Martín-Diana, Barat, & Barry-Ryan, 2007). For these reasons, the shelf life of minimally processed fruit tends to be short, and extending it by even few days could represent a considerable advantage (Manzocco, Da Pieve, & Maifreni, 2011). As consumers demand healthy products, natural substances which are able to act as antimicrobials in minimally processed foodstuffs have garnered much interest in recent years.

Edible coatings minimize the respiration rate of the fruit (Park, 1999) and can also serve as a barrier to water vapor, reducing microbial proliferation and delaying dehydration. Edible coatings based on polysaccharides have been used to effectively prolong the shelf life of some climacteric fruits (Vargas, Pastor, Chiralt, McClements, & González-Martínez, 2008). Alginate and chitosan based edible coatings have good water and gas barrier properties and are abundant, cheap and natural. A recent review about the chitosan coatings properties and uses to prolong the shelf life of vegetables has been found in the literature (Elsabee & Abdou, 2013). Chitosan needs an acidic media to completely get dissolved and acetic acid is widely used for this purpose. However, Campaniello, Bevilacqua, Sinigaglia, and Corbo (2008) used a citric acid solution and Han, Lederer, McDaniel, & Zhao (2005) compared the effects of a chitosan based edible coating dissolved into lactic or acetic acid to maintain the quality of strawberries. The effectiveness of alginate edible coatings has been studied in apples (Olivas, Mattinson, & Barbosa-Cánovas, 2007), pineapples (Montero-Calderón, Rojas-Graü, & Martín-Belloso, 2008) papayas (Tapia et al., 2008) and other fruits. Alginate-based coatings maintained the firmness of apple slices for eight days, reduced juice leakage in pineapple slices and reduced the respiration rate of papaya

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cylinders. Aloe vera gel is a polysaccharide matrix rich in active compounds that has been used for centuries due to its medicinal and therapeutic properties (Ni, Turner, Yates, & Tizard, 2004). Aloe vera and its physiologically active substances have been the topic of several reviews (Choi & Chung, 2003; Eshun & He, 2004; Rodriguez, Martin, & Romero, 2010).

The mucilage or gel of the Aloe vera leaf consists of approximate 99.5% water and 0.5% of solid material that includes compounds like polysaccharides, vitamins, minerals, enzymes, phenolic compounds and organic acids (Boudreau & Beland, 2006). The major polysaccharides include not only cellulose and hemicellulose but also storage polysaccharides like glucomannans, mannose derivatives and acetylated compounds. There are large fluctuations in the polysaccharide composition that can be attributed to significant seasonal influence, as well as large variations between cultivars (Femenia, Sanchez, Simal, & Rosello, 1999). Although different results on the composition of polysaccharides in aloe pulp have been described in the literature, the consensus among most authors is that acetylated glucomannan molecules are mainly responsible for the thick, mucilage-like properties of the raw aloe gel (Hamman, 2008). The many advantages of Aloe vera gel, such as its antimicrobial activity and ease of preparation, make it viable for use as an edible coating. Aloe vera based coatings have been used with table grapes and sweet cherries to maintain quality and reduce microorganism proliferation (Martínez-Romero et al., 2006; Serrano et al., 2006; Valverde et al., 2005). Also Aloe coatings (*Aloe arborescens* and *Aloe vera*) reduce weight loss and ethylene production in raw peaches and plums (Guillén et al., 2013). In a recent study with fresh-cut kiwifruit, Aloe vera was effective in reducing pectin depolymerization and microbial proliferation. Furthermore, the sensorial quality was enhanced (Benítez, Achaerandio, Pujolà, & Sepulcre, 2013).

Several preservation technologies, comprising the combination of cold storage with calcium salt dips (Antunes et al., 2007), modified atmosphere (Hertog, Nicholson, & Jeffery, 2004), the combination of a polyolefin film with methylcyclopropene (Li, Wang, et al., 2011) or edible coatings (Diab, Biliaderis, Gerasopoulos, & Sfakiotakis, 2001; Du, Gemma, & Iwahori, 1997; Fisk, Silver, Strik, & Zhao, 2008; Xu, Chen, & Sun, 2001) have been used to prolong the postharvest quality of whole kiwifruits. Hertog et al. (2004) concluded that low CO_2 (<2.5% CO_2) concentrations reduced the tissue softening of whole kiwifruits but not their respiration rate. They also found that the additional effect of this modified atmosphere was limited at temperatures over 3 °C. These results suggest that modified atmosphere packaging has to be used in combination with another technique in order to obtain the best results. Diab et al. (2001) showed that pullulan-based coatings prevent moisture loss in kiwifruits. Xu et al. (2001) concluded that an edible coating made of soy protein concentrate retards the senescence process of whole kiwifruits. Additionally, chitosan coating applied in whole kiwifruit reduces postharvest decay by preventing surface moisture loss (Du et al., 1997; Fisk et al., 2008).

Studies concerning the quality maintenance of fresh-cut kiwifruit entail conventional or alternative modified atmosphere packaging (Li, Li, Sun, Cao, & He, 2011; Rocculi, Romani, & Rosa, 2005), antibrowning agents dips (Antunes, Rodrigues, Cavaco, & Miguel, 2011), essential oils (Roller & Seedhar, 2002), volatile compounds sprays (Wang & Buta, 2003) and mild heat treatments (Beirão-da-Costa et al., 2008). However, for the authors' knowledge, there is little evidence related to the application of edible coatings to maintain the quality of kiwifruit slices. Mastromatteo, Mastromatteo, Conte, and Del Nobile (2011) found that an alginate coating applied to peeled kiwifruits was effective in delaying the dehydration of the fruit and slowing down its respiratory activity. Along with the increased interest in ready-to-eat fruit with a high nutritional value, edible coatings may be a natural alternative for the production of high-quality kiwifruit slices. Therefore, the objectives of our research were to study the effectiveness of an alternative coating formulated with Aloe vera, and to compare it against chitosan (formulated with different organic acids) and an alginate based coatings applied in fresh cut 'Hayward' kiwifruit during 12 days of refrigerated storage (4 ± 1 °C).

2. Materials and methods

2.1. Plant material

Kiwifruits (*Actinidia deliciosa* cv. Hayward) were obtained from Mercabarna (Mercados de Abastecimientos de Barcelona S.A., Barcelona, Spain) and stored at 2 ± 1 °C for 3–5 days until processing. The ripening stage of kiwifruits corresponds to 12.6 ± 0.13 °Brix, 1.08 ± 0.02 g citric acid per 100 g of fresh weight and 3.49 ± 0.01 for soluble solid content, titratable acidity and pH, respectively. The kiwifruits were washed and sanitized with chlorinated water (200 mg/l) for 5 min at 15 °C and rinsed with tap water, drained for 5 min, hand peeled and cut into 6 mm slices with a stainless steel slicer. The slices were randomly distributed among treatments.

2.2. Edible coating preparation and application

Based on the concentrations of alginate and chitosan coatings published on the literature (Chien, Sheu, & Yang, 2007; Devlieghere, Vermeulen, & Debevere, 2004; Olivas et al., 2007; Oms-Oliu, Soliva-Fortuny, & Martín-Belloso, 2008) a preliminary experiment was conducted to determine which ones would be most effective in extending the quality of kiwifruit slices. It was determined that 2% (w/v) alginate and 1% (w/v) chitosan were the most promising formulation based on gas concentrations, adherence of the edible coatings and overall visual quality of kiwifruit slices (data not shown). The Aloe vera concentration was chosen based on our previous study (Benítez et al., 2013).

Chitosan (Sigma–Aldrich Química S.L., Madrid, Spain) (1%, w/v) was dispersed in acetic acid solution (1%, v/v) or in citric acid solution (2%, w/v) by means of gentle stirring. Alginate powder (Sigma–Aldrich Química S.L., Madrid, Spain) (2%, w/v) was dissolved in distilled water under controlled heating conditions (80 °C) and stirred until the mixture was clear. A calcium lactate (Sigma–Aldrich Química S.L., Madrid, Spain) (2%, w/v) bath for carbohydrate polymer cross-linking was used after alginate dipping. 5% Aloe vera edible coating was prepared by diluting 200 ml of Aloe vera gel (food grade), obtained from AVISA (Aloe Vera Internacional S.A., Fuerteventura, Spain), in 4 l of distilled water. Slices were immersed for 10 min at ambient temperature and slices immersed in distilled water were used as control samples. Following treatment, the samples were air dried for 15 min before packaging. 45 g (4 slices) of kiwifruit were packed on polypropylene trays (450 ml) and sealed with a composite film (PP-PET, $PO_2 = 1.1 \times 10^{-3}$ ml/m^2/24 h/Pa, $PCO_2 = 5 \times 10^{-3}$ ml/m^2/24 h/Pa) (Tecknopack, Mortara, Italy). The kiwifruit slices were then stored at 4 ± 1 °C and 75% relative humidity (RH) for 12 days for subsequent analysis. Three trays of each treatment were randomly selected for analysis each day of control. There were 250 packages in total, resulting in 50 packages per treatment.

2.3. Physicochemical analysis

2.3.1. Headspace gas composition

The CO_2 and O_2 composition of the atmosphere in the trays was measured using a Checkmate II gas analyzer (PBI Dansensor,