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Development of a cactus-mucilage edible coating (*Opuntia ficus indica*) and its application to extend strawberry (*Fragaria ananassa*) shelf-life

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Abstract

Increased consumer demand for higher quality food in combination with the environmental need to reduce disposable packaging waste have led to increased interest in research into edible films and coatings. In this work, the use of prickly pear cactus mucilage (*Opuntia ficus indica*) was investigated as an edible coating to extend the shelf-life of strawberries. Different methods for mucilage extraction were tested in order to obtain the best coating. Edible films were tested to determine their effects on colour, texture and sensory quality of the fruit. From the results, it was concluded that the use of mucilage coatings leads to increased strawberry shelf-life.

Keywords: Edible films; Prickly pear cactus mucilage; Strawberry shelf-life; Sensorial analysis; Texture and colour properties

1. Introduction

Strawberries are delicate and perishable fruits, susceptible to mechanical damage, physiological deterioration, water loss and decay (Sanz, Pérez, Olías, & Olías, 1999). They have a very short post-harvest life, and losses can reach 40% during storage (Satin, 1996). Reduction in turgidity as a result of water loss causes shrivelling and faster depletion of nutrients and organoleptic properties, and is a major cause of fruit deterioration (Nunes, Brecht, Morais, & Sargent, 1998). In Chile, cold storage of strawberries is not very common and this fruit is usually stored in markets at room temperature between harvest and consumption. For this reason, product losses are very high. With the use of edible coatings and cold storage, spoilage could be minimised (Xu, Chen, & Sun, 2001).

Generally, edible films and coatings, which can be divided into proteins, polysaccharides, lipids and composites, are defined as thin layers of edible material formed on a food surface as a coating, or placed (pre-formed) between food components. Their purpose is to extend the shelf-life of the food product and provide a barrier against hazards. They can retard moisture migration and the loss of volatile compounds, reduce the respiration rate, and delay changes in textural properties. Also, they are excellent barriers to fats and oils, and have a high selective gas permeability

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ratio CO_2/O_2 as compared to conventional synthetic films (Gontard, Thibault, Cuq, & Guilbert, 1996). They can also act as carriers of food additives such as antioxidants and/or antimicrobial agents and can improve mechanical integrity or handling characteristics of the food. Stand-alone edible films with good mechanical properties could replace synthetic packaging films for specific applications (Krochta & DeMulder-Johnston, 1997; Pérez Gago & Krochta, 1999).

Edible films and coatings afford numerous advantages over conventional non-edible polymeric packaging. They can reduce the complexity of the food package and, even if they are not consumed with the packaged product, can contribute to the reduction of environmental pollution by virtue of their biodegradable nature.

In the specific case of fruits and vegetables, the effectiveness of edible coating depends primarily on the selection of appropriate material, which results in beneficial internal gas composition (Park, Chinnan, & Shewfelt, 1994). Edible coatings based on cellulose have been extensively applied to delay loss of quality in fresh products such as tomatoes, cherries, fresh beans, strawberries, mangoes and bananas (Ayranci & Tunç, 1997; Baldwin et al., 1999; Kittur, Saroja, Habibunnisa, & Tharanathan, 2001; Yaman & Bayoındırh, 2002; Zhuang, Beauchat, Chinnan, Shewfelt, & Huang, 1996). Chitosan is another polysaccharide widely used in the post-harvest decay control of fresh fruits and vegetables (El Ghaouth, Arul, & Ponnampalam, 1991a, 1991b; Kittur, Kumar, & Tharanathan, 1998). Proteins, such as casein, whey proteins and corn zein, have also been used as a moisture barrier since these proteins are abundant, cheap and readily available (Cuq, Gontard, & Guilbert, 1998).

However, the hydrophilic nature of these polysaccharides and proteins limits their ability to provide the desired edible film functions. Current approaches to improve water barrier and mechanical properties of these films include incorporation of hydrophobic compounds, optimisation of interaction between polymers and formation of cross-links (Vachon, D'Apprano, Lacroix, & Letendre, 2003).

Polysaccharides capable of forming gels in water are common throughout the plant kingdom. Some of them, such as the pectins in higher plants, carrageenans and agarose in algae, algal and bacterial alginates and xanthan, have been investigated in great detail. A relatively good understanding, of their biochemistry and biophysical properties has already been achieved. By contrast, the composition properties or food applications of mucilages have been much less studied (Trachtenberg & Mayer, 1982).

Mucilages are generally hetero-polysaccharides obtained from plant stems (Trachtenberg & Mayer, 1981). There are few studies on the composition and properties of *Opuntia ficus-indica* mucilage. McGarvie and Parolis (1979) determined that the mucilage extracted from the stems contains residues of D-galactose, D-xylose, L-arabinose, L-rhamnose and D-galacturonic acid.

Cactus mucilage may find applications in food, cosmetics, pharmaceutical and other industries. The complex polysaccharide is part of dietary fibre and has the capacity to absorb large amounts of water, dissolving and dispersing itself and forming viscous or gelatinous colloids (Dominguez-López, 1995).

An important point in the choice of the cactus mucilage as a coating is its low cost. The cactus needs to be pruned; therefore, the cactus stems are a waste product capable of several applications, such as aforementioned.

The aim of the present work is a preliminary study of the suitability of prickly pear cactus (*O. ficus indica*) mucilage as an edible coating to extend the shelf-life of strawberries.

2. Materials and methods

2.1. Materials

Strawberries (*Fragaria ananassa*), common consumer varieties, were purchased from a local market on the day after harvest and were immediately placed in cold storage (5 °C ± 0.5). Fruits were selected by uniformity in size and were defect-free. Cactus stems were obtained from a local farmer and were stored at 23 °C ± 1 prior to formation of the coating solution. Glycerol (99.5%) was purchased from Sigma Chemical Co.

2.2. Methods

2.2.1. Coating solution preparation

Cactus stems were peeled and cubed (1 cm^3). Samples were homogenised (20% *w/v)* in distilled water. The slurry was centrifuged for 10 min at $4500 \times g$ and the supernatant obtained was used to prepare the edible coating (Sáenz, Vásquez, Trumper, & Fluxá, 1992). Two experimental coatings were formulated: M1, pure mucilage extract and M2, mucilage extract and 5% *w/w* glycerol as a plasticizer. Strawberries were dipped in coating solution for 30 s, the excess coating was drained and the coated strawberries were dried in a forced-air dryer (20 °C) for 30 min. Strawberries dipped in distilled water were used as a blank. After the coating process, strawberries were stored in a refrigerator at 5 ± 0.5 °C and 75% RH for 10 days. For each treatment and storage time, 50 fruits were coated. Three replications per treatment were analysed after 1, 3, 5, 7 and 9 days for sensorial analysis and, after 1, 5 and 9 days for texture and colour properties.

2.2.2. Firmness

This property was evaluated, in 25 fruits with a TA-TX2i Texture Analyser (Stable Micro Systems Ltd.) by measuring the force required for a 2 mm probe to penetrate 6 mm fruits at a rate of 1 mm/s. Samples were placed in a way that the probe penetrated their equatorial zone.

2.2.3. Colour

Three CIE (Commission International de I'Eclairage) $L*a*b*$ values of 25 fruits for each treatment and storage time were directly read with a CR-200 portable tristimulus colorimeter (Minolta, Ramsey Corp. NY) with a D_{65} light source and the observer at 2°. Colour coordinates range from $L = 0$ (black) to $L = 100$ (white), −a (greenness) to +a (redness), and −b (blueness) to +b (yellowness). A Minolta standard white plate ($L* = 92.4$, $a* = -0.7$, $b* = -0.9$) and black plate were used for instrument standardisation.

2.2.4. Sensorial analysis

A panel of 16 trained judges carried out sensory analysis. Two kinds of tests were performed: (i) a preference test; (ii) an acceptability test with a nine-point hedonic scale. In the preference test the judges had to choose one preferred sample according to their general preferences. The acceptability test was carried out using semi-structured scales, scoring one (lowest) to nine (highest). The attributes evaluated were: visual appearance, colour, brightness, texture and taste. The judges' average response was calculated for each attribute. Overall acceptability was calculated by weighted arithmetic means, giving the following weight to each attribute: visual appearance 30%, colour 10%, brightness 25%, texture 25% and taste 10%, according to the influence of each attribute on acceptance of the product by consumers. Samples were considered acceptable if their mean value for overall acceptability was equal to or above five (neither like nor dislike).

2.2.5. Statistical analysis

Analysis of variance and Duncan's multiple-range test with $p < 0.05$ were employed to statistically analyse all results. The Student's t test was utilized at the time of the analysis of variance and paired-comparison with $p < 0.05$.

3. Results and discussion

3.1. Firmness

Fig. 1 shows the firmness evolution of control and coated strawberries during storage at 5 ± 0.5 °C for nine days. It can be observed that, in spite of standard deviation values typical of biological samples, M_1 and M_2 coatings increased the firmness of the fruits at the end of the holding period, nine days. In general, firmness of native fruits declined from 92 ± 9 to 73 ± 10 N after nine days of storage. For samples coated with M1 and M2 formulations, firmness decreased from 153 ± 20 to 101 ± 10 N and from 135 ± 21 to 107 ± 12 N, respectively.

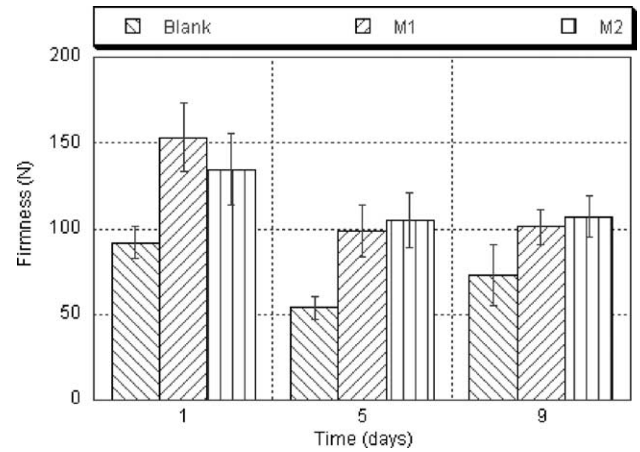

Fig. 1. Effect of edible coating on strawberries' firmness as a function of storage time.

After the first day of storage, M1 and M2 formulations increased the firmness of strawberries with respect to control; samples coated with M1 formulation achieved the highest firmness value. After the fifth day of storage, a general firmness reduction was observed for both coated and uncoated samples, the coated samples maintaining greater firmness values than control. This tendency was prolonged until the end of the storage period, ninth day. No statistical differences were observed between samples coated with M1 and M2 formulations during the entire storage period.

These results are in agreement with those of El Ghaouth et al. (1991a, 1991b) where retention of flesh firmness of strawberries was achieved by a chitosan coating. Diab, Biliaderis, Gerasopoulos, and Stakiotakis (2001) also delayed loss of firmness in this fruit by applying a pullulan-based edible coating. During storage, the texture of the fruits is likely to soften due to several factors, including loss in cell turgidity pressure, loss of extracellular and vascular air and the degradation of the cell wall and consequent loss of water by the cell breakdown (Martínez-Ferrer, Harper, Pérez-Muñoz, & Chaparro, 2002; Somogyi, Hui, & Barret, 1996). Despite the hydrophilic character of polysaccharides, they can act as a barrier to water transfer, retarding dehydration and, therefore, prolonging the firmness of the coated fruit. Addition of glycerol at 5% to the coating solution had little effect on the firmness of coated strawberries, not being statistically significant. Glycerol was added to increase the flexibility of the coating and hence avoided splitting on the coated fruit. Cracking of the coating lacking glycerol was not observed since water itself acted as a plasticizer, due to the high water activity of strawberries.

3.2. Colour properties

As can be seen in Fig. 2(a), coating of fruits did not produce significant changes in the *L* coordinate of strawberries during storage time, which had values around 33 ± 5. This can demonstrate that the coating did not produce alterations in the typical lightness o the product.

Fig. 2(b) shows the evolution of redness of control and coated samples. It can be observed that the coating did not produce modification of the *a* coordinate compared to the control. After the first day of storage, all the samples showed *a* values of around 55 ± 2. From the fifth day of storage, this coordinate decreased by 40% for coated and uncoated samples and maintained a constant value until the 9th day, presenting values around 33 ± 0.84. This decrease in the redness is probably due to an increase in respiration rate and enzymatic processes that lead to a loss of quality of the fruit involving, browning among other reactions. As regards the yellowness values (Fig. 2(c)), maintenance of *b* values can be observed for all samples (coated and uncoated) from the first to the ninth day, 16 ± 1.5 and 17 ± 1.5, respectively.

Strawberry colour is a very important attribute for consumer product acceptance and although coating did not modify the original colour of the fruit, neither did it delay browning. Addition of glycerol to the coating solution did not have any effect on colour properties of the samples.

3.3. Sensorial analysis

Fig. 3 shows the judges' preference evolution during the nine days of storage. It can be observed that, after the first day of storage, M2 showed the lowest preference percentage, while samples coated with formulation M1 and uncoated samples showed similar preference percentages. For uncoated fruits, preference percentage decreased with storage time whereas, from the first week of storage, the coated samples were the preferred choice for the judges, presenting a statistical difference with respect to the control sample. After seven days of storage, sample M2 presented a higher preference value than sample M1. Since glycerol is a hygroscopic agent its incorporation into the hydrocolloid formulation can have a beneficial effect with storage time on coated strawberries, helping to retain moisture on the fruit surface and imparting a fresh appearance. However, nine-

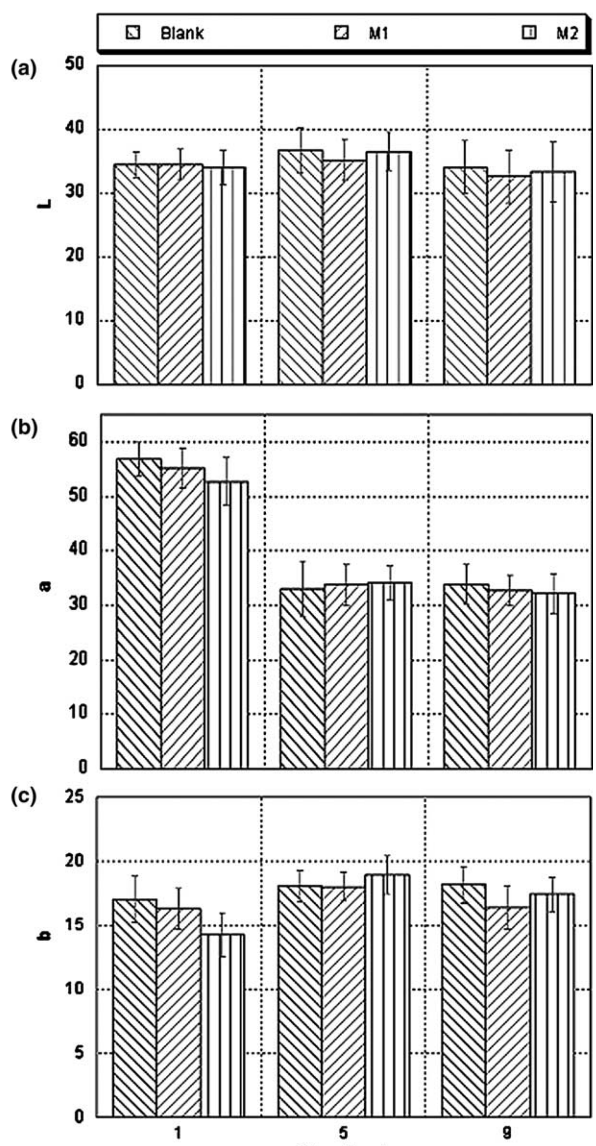

Fig. 2. Colour parameter (*L, a, b*) evolution of control and coated strawberries with M1 and M2 formulations during storage.

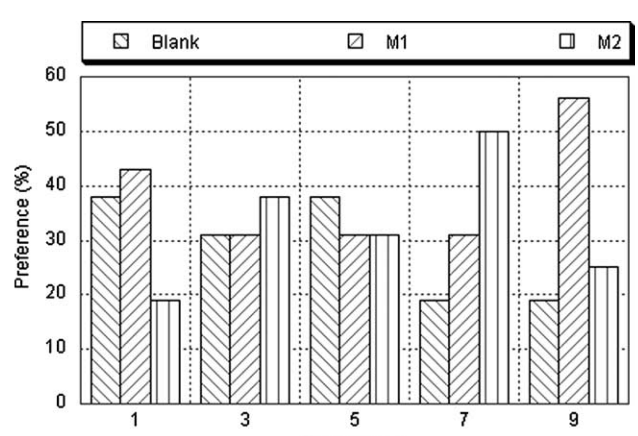

Fig. 3. Judges' preferences of coated and non-coated samples during storage time.

day samples, coated with formulation M1, presented the highest preference percentage (above 50%).

Fig. 4 represents visual appearance, colour, brightness, texture, taste and general acceptance scores for control and samples coated with the M1 and M2 formulations. It can be observed that, initially, M2 coated fruits had lower scores than M1 and control in all the sensorial attributes evaluated, as recorded in the preference test. There were no significant differences between M1 coating and control. It should be pointed out that, although lower scores were obtained for taste in M2-coated strawberries, judges did not describe it as the presence of an off-flavour. After five days of storage, slightly better results for colour and general acceptance were obtained for M2-coated strawberries. García, Martino, and Zaritzky (1998a, 1998b) also reported that the addition of glycerol to a starch-based coating considerably improved the appearance, flesh firmness and organoleptic characteristics of coated strawberries. However, in that study, a greater amount of glycerol was added to avoid cracking and brittleness of the coating. Coated and uncoated samples showed similar scores after nine days of storage except for the texture attribute, which showed better scores for samples coated with formulation M1. However, as has been shown above, instrumental analysis of texture did not show significant differences between samples coated with the M1 and M2 formulations.

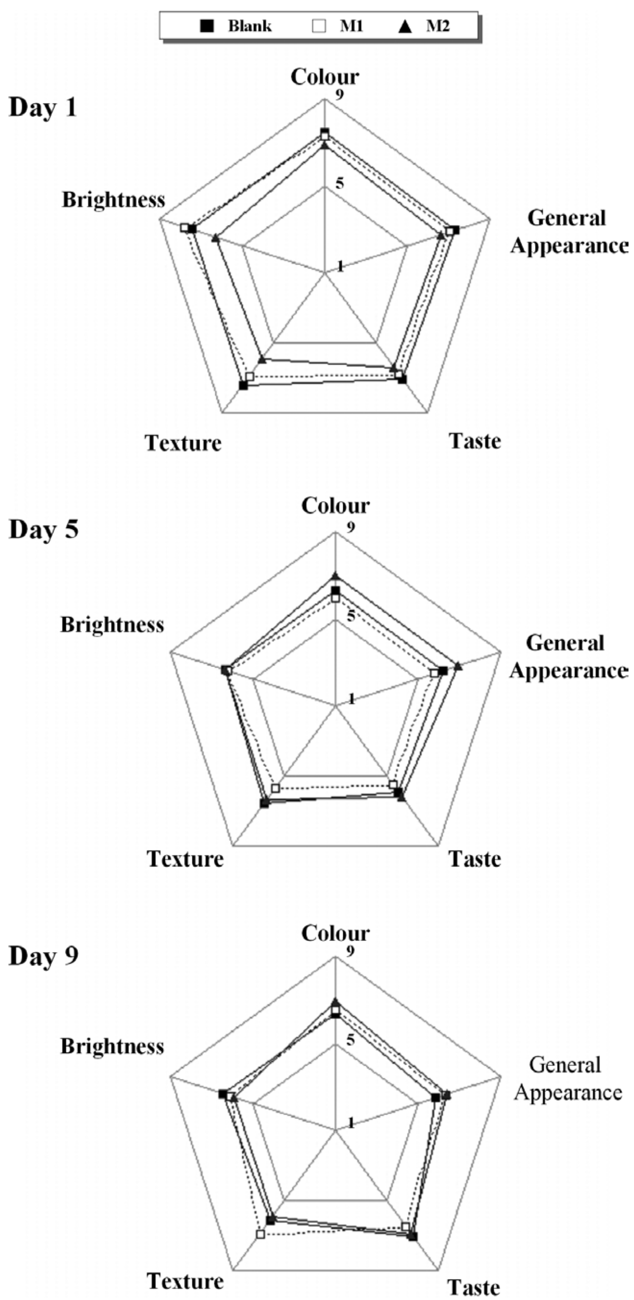

Fig. 4. Scores of samples (control, coated with M1 and M2 formulations) after 1, 5 and 9 days of storage.

4. Conclusions

Textural analysis showed that prickly pear cactus mucilage could have a protective effect on strawberries, reflected by the greater firmness of coated samples during storage, which could reduce economic losses due to spoilage produced from mechanical damage during handling and transportation. Colour properties of the samples were not affected by the coating as compared to the blank.

Sensorial analysis showed that judges had a preference for coated samples at the end of the nine-day holding period. The coating did not affect the natural taste of strawberries, which is an important aspect regarding the use of edible coatings when taste modification is undesirable.

Overall, the coating showed a tendency to prolong the strawberry shelf-life, maintaining physical and sensorial properties. However, it is possible that the cold temperature, added to the coating effect, might have helped the product to maintain its own characteristics. Further, research has to be done at storage temperatures close to room temperature conditions, in order to fully characterize the effect of the coating itself on the quality of the samples.

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