

Chemical dips and edible coatings to retard softening and browning of fresh-cut banana

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Abstract: The effects of chemical dips and edible coatings on firmness and colour of fresh-cut banana (cv. Cavendish) from Madeira Island were investigated. Two calcium salts, calcium chloride and calcium lactate, were first investigated for the effects on firmness during four days of storage at 5°C. Firmness and colour were evaluated after a three-minute chemical dipping or chemical dipping followed by coating and during five days of storage at 5°C. The coatings tested consisted of pectin, alginate, carboxymethylcellulose, carrageenan or chitosan solution. Dip with 1% (w/v) calcium chloride, 0.50% (w/v) ascorbic acid and 0.75% (w/v) cysteine was the most efficient treatment in retarding softening and browning of banana slices. This dip also inhibited yeast growth. According to sensory analysis, the edible shelf life of banana slices dipped in such solution was the longest: five days at 5°C. Carrageenan solution was the significantly ($p < 0.05$) best coating among the ones studied, in preserving firmness and colour of fresh-cut banana during five days at 5°C.

Keywords: fresh-cut banana; chemical dip; coating; firmness; colour.

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1 Introduction

Over the years, different physical and chemical techniques have been developed to extend the shelf life of fresh-cut produce: refrigeration, disinfection (Hong and Gross, 1998), ethylene absorbers (Abe and Watada, 1991), gamma irradiation (Chervin and Boisseau, 1994), edible coating (Baldwin et al., 1995), chemical dipping (Vilas-Boas and Kader, 2006), controlled/modified atmosphere packaging (Brecht, 1999). Because different fruits react differently to different treatments, it is imperative that the right combination of these techniques is determined for each kind of fruit.

Texture and colour are two of the most noticeable quality parameters of fresh-cut fruits and vegetables that may change during storage. Application of calcium compounds (usually 1% CaCl_2 dips) helps to maintain the firmness of fresh-cut apple, pear, strawberry and banana (Vilas-Boas and Kader, 2006). The use of calcium chloride as firming agent, however, may impart bitterness or flavour differences (Olsen et al., 1966; Bolin and Huxsoll, 1989; Monsalve-Gonzalez et al., 1993). A residual amount of calcium chloride remains on the surface of the product after the dip treatment thus increasing the

probability of bitterness detection by the consumer (Luna-Guzman and Barrett, 2000). The bitterness and salty taste caused by calcium chloride may be suppressed when calcium is combined with larger ions such as lactate, gluconate or glycerolphosphate (Lawless et al., 2003).

The thiol containing amino acid cysteine has been reported to effectively inhibit PPO-mediated enzymatic browning of fruit and vegetables (Joslyn and Ponting, 1951). Kahn (1985) reported that L-cysteine was shown to be the most effective inhibitor of browning in banana and avocado tissues.

Edible coatings have been used to preserve whole or fresh-cut produce since they may act as a barrier to water loss and oxygen access. The basic composition of edible coatings for fresh-cut fruits may include hydrocolloids and lipids. These hydrocolloids (proteins and carbohydrates) tend to form hydrophilic networks, usually being a good barrier to oxygen and carbon dioxide, but a poor barrier to water. Some polysaccharides that have been successfully used to coat fresh-cut fruits include carrageenan, maltodextrin, methylcellulose, carboxymethyl cellulose (CMC), pectin, alginate, chitosan, starch and microcrystalline cellulose (Debeaufort et al., 1998; Olivas et al., 2003; Pavlath et al., 1993; Rouse and Moore, 1972; Thommohaway et al., 2007; Wong et al., 1994).

The functional, nutritional, sensory and mechanical properties of the coating can be improved by the use of additives like anti-browning agents, preservatives, firming agents, plasticisers, nutraceuticals, volatile precursors, flavours and colours (Vojdani and Torres, 1990; Baldwin et al., 1996). Glycerol and polyethylene glycol (PEG) are the most often used plasticisers for cut fruits (Wong et al., 1994). These substances have the ability to modify the mechanical properties of the coatings by polymer chains, moving the chains apart and reducing the rigidity of the structures (Guilbert and Biquet, 1996).

Currently, there is little information about the combined effect of edible coatings and chemical dips on fresh-cut fruits. Moreover, only few research works have been conducted on fresh-cut banana and none was performed on banana from Madeira Island. Vilas-Boas and Kader (2006) studied the effect of combined effect of chemical dip and atmosphere composition on fresh-cut banana. Controlled atmosphere may be used as a hurdle technology for improvement of the protection against softening and browning of banana slices provided by carrageenan coating and chemical dip (Bico et al., 2009). Moline et al. (1999) proved that 0.5 M citric acid and 0.05 M N-acetylcysteine prevented browning at 5°C and 15°C during seven days.

Therefore, the objectives of this study were to maintain fresh-like quality (colour and firmness) of fresh-cut slices of 'Cavendish' banana from Madeira Island at 5°C, by using chemical dips combined with edible coatings.

2 Material and methods

2.1 Plant material

Bananas (*Musa acuminata* Colla, cv. Cavendish) from Madeira Island at ripeness stage 4 (peel more yellow than green) and free of visible physical and fungal infection were purchased from the central market of Porto, Portugal (MAP). The bananas were

transferred to the laboratory and were stored at $13 \pm 1^\circ\text{C}$ and 65% relative humidity (RH) until processing that happened within a week.

2.2 *Preparation of chemical dips*

The chemical dips used in the experiment were: 1% (w/v) calcium chloride, 0.5% (w/v) ascorbic acid and 0.75% (w/v) cysteine, and 2% calcium lactate, 0.5% ascorbic acid and 0.75% cysteine.

Sterilised distilled water was used in the preparation of the chemical solutions to prevent from contamination with micro-organisms.

2.3 *Preparation of edible coatings*

2.3.1 *Alginate coating*

Alginate coating was prepared according to Rojas-Grau et al. (2007). Two grams of sodium alginate ($\text{NaC}_6\text{H}_7\text{O}_6$, BDH, Poole, England) was dissolved in 100 ml sterilised distilled water and heated at 70°C , until the solution became clear. After cooling, glycerol [$\text{C}_3\text{H}_5(\text{OH})_3$, 85% purity, Merck, Darmstadt, Germany] was added as plasticiser to a final concentration of 1.5 g/100 ml solution. The solution was emulsified with sunflower oil (0.025 g/100 ml coating solution) at 24,500 rpm for five minutes, before pH adjustment to 5.6 by using 50% (w/v) citric acid ($\text{H}_3\text{C}_6\text{H}_5\text{O}_7$, Sigma Co., St. Louis, MO, USA).

2.3.2 *CMC coating*

CMC coating preparation was adapted from Lee et al. (2003). 0.20 g CMC (CEKOL 100,000, CPKelco, Denmark) was dissolved in 50 ml sterilised water. The solution was heated to 90°C . A 50 ml solution containing 0.08 g glycerol was added prior to stirring for 20 minutes. The pH was then adjusted to 5.6 by using 1.0 M NaOH.

2.3.3 *Carrageenan coating*

Carrageenan coating was prepared according to Lee et al. (2003). 0.5 g carrageenan (GENEGEL CJ, CPKelco, Denmark) was dissolved in 100 ml sterilised distilled water. A 50:50 (w/w) mixture of glycerol and PEG 4000 (Merck, Darmstadt, Germany) was used as plasticiser (0.75 g/g carrageenan). The solution was equilibrated at 70°C and stirred vigorously with a magnetic stirrer bar for 40 minutes, on a hot plate. The solution was cooled down to room temperature prior to pH adjustment (5.6) by using 50% citric acid.

2.3.4 *Chitosan coating*

Chitosan coating was prepared according to Vargas et al. (2006). One gram of chitosan (1% w/v) (Sigma Aldrich, Switzerland) was dispersed in an aqueous solution of glacial acetic acid (1% v/v) at 40°C . Tween 80 at 0.1% was added to improve wettability. After eight hours of stirring, olive oil was added to chitosan solution to a final concentration of 2% (v/v). The mixture was emulsified by stirring for four minutes before adjusting the pH to 5.6 by using 1.0 M NaOH.

2.3.5 Pectin coating

Pectin coating preparation was adapted from Maftoonazad et al. (2007). A 0.5% (w/w) pectin solution was prepared by rehydrating pectin (GENU LM-104 AS-FS, CPKelco, Denmark) in sterilised distilled water (12 hours at 20°C) and 0.05% (w/v) of sorbitol (Sigma Co., St. Louis, MO, USA). The mixture was homogenised with magnetic stirring until it became clear. Then 0.05% (w/v) melted beeswax was added and emulsified by using a homogeniser at 14,000 rpm for four minutes, prior to pH adjustment (5.6) by using 1.0 M sodium hydroxide (NaOH, Sigma Co., St. Louis, MO, USA).

2.4 Sample preparation

Bananas were washed with running water, dipped into chlorinated water (0.75% active chlorine) for five minutes and room temperature forced air-dried. The banana was then peeled and sliced (1 cm thickness) with a sharp sterilised knife in a laminar flow chamber. Ten similar slices were taken from each banana. Three replicates of ten slices from different bananas per treatment and per day were analysed for the effect of chemical dipping and/or edible coating. The samples were placed in an ice bath immediately after cutting.

Two different treatments were used:

- 1 dip alone
- 2 dip + coating.

In the two treatments, banana slices were dipped into the chemical solution for three minutes. The excess solution was allowed to drip off the banana slices surface for five minutes on tissue paper, and stored in 250 ml opened plastic containers. In treatment 2, chemically dipped bananas were coated with a specific solution, and the excess solution was drip off the surface of the slices for one minute, before storage in the plastic containers. All samples were stored at 5°C and 55% RH.

Slices dipped in distilled water were used as control. The temperature of the chemical dips and the distilled water used were maintained at 5°C while the coating solution, previously stored at 20°C, was kept at room temperature.

2.5 Firmness evaluation

Firmness of each slice was determined with a Texture Analyzer Plus (TA-XT, Stable Micro Systems, UK) by measuring the force required for a 2 mm probe to penetrate 10 mm into the cut surface. Each slice was punctured thrice in each opposite side. A load of 20 N was used. Maximum force was registered. Firmness determinations were performed in triplicate. Ten slices per replicate were used for the analysis.

2.6 Colour evaluation

Colour on opposite sides of each slice was measured with a hand-help tristimulus reflectance colourimeter (Minolta CR-300, Minolta Corporation, Ramsey, NJ) in the CIE $L^*a^*b^*$ mode CIELAB colour space (CIE, 1978). Chroma (C) was calculated by using

the formula $C = (a^2 + b^2)^{1/2}$. Colour determinations were performed in triplicate. Ten slices per replicate were used.

2.7 Sensory analysis

Sensory evaluation was performed by 20 trained panelists, after five days of storage at 5°C, on samples that had been dipped in 1% (w/v) calcium chloride (CaCl₂), 0.50% (w/v) ascorbic acid and 0.75% (w/v) cysteine or dipped in this solution and coated with carrageenan solution. The parameters evaluated were global appreciation, colour, odour, texture and flavour. The following scale was used for scoring these attributes: 1, very bad; 3, neither good nor bad, 5, very good.

2.8 Statistical analysis

The SPSS 11.5 for Windows (Chicago, Illinois, USA) was used for the analysis of data. Statistical significance was assessed by one-way analysis of variance. The overall least significance difference (LSD; $p = 0.05$) was calculated and used to detect significant differences among storage times. Relationships among measurement variables were studied by using the correlation factor (R).

3 Results and discussion

3.1 Effects of calcium salt in chemical dips

The first part of this research dealt with the selection of the chemical dip solution that can reduce softening and browning rates of banana slices. The firming agent, calcium ion, and some antioxidants (ascorbic acid and cysteine) composed the chemical dips. To determine the effect of two salts (calcium chloride and calcium lactate) on firmness of banana slices, the same calcium concentration (0.09 mol Ca /L) was used in the dipping solutions with also the same amount of ascorbic acid (0.50%) and cysteine (0.75%).

Untreated banana slices (control) had firmness loss of 52% (from 0.97 N to 0.47 N) after four days of storage at 5°C. Both chemically dipped samples were significantly firmer than water dipped one (control) from the second day of storage, but no difference was observed between the effects of dip with calcium chloride and dip with calcium lactate during storage. At the end of storage (four days) they presented 0.71 N and 0.69 N, respectively. Luna-Guzman and Barrett (2000) reported that a similar or better tissue firming effect was observed when using 2.5% calcium chloride or 2.5% calcium lactate than water dip on fresh-cut cantaloupe. Agar et al. (1999) reduced the softening of kiwifruit slices by dipping into 0.5% or 1% calcium chloride, or 0.5% calcium lactate.

However, pinking was observed in samples treated with dip with calcium lactate. This may be an indicator of yeast growth. In fact, microbiological analysis carried out in the Microbiology Laboratory of the Associação para a Escola Superior de Biotecnologia da Universidade Católica (AESBUC), Porto, Portugal, identified the yeast *Cryptococcus humiculus* in samples treated with calcium lactate after two days of storage. Difference in pH (dip 1 and dip 2 have pH values of 2.80 and 4.30, respectively) and source of calcium salts may have triggered the growth of the yeast. Mountney and Gould (1988) reported that yeasts and moulds can grow in pH range of 4 to 4.5.

Richard et al. (1991) found that when cysteine is used as inhibitor of enzymatic browning, pinkish-red coloured compounds may be formed due to phenol regeneration with deep colour formation. Vilas-Boas and Kader (2006) reported that pinking occurs in banana slices if cysteine concentration is less than 0.5%. A 2 min dip in a mixture of 1% (w/v) CaCl_2 + 1 % (w/v) ascorbic acid + 0.5% (w/v) cysteine effectively prevented browning and softening of banana slices for six days at 5°C. Dips in cysteine with concentrations between 0.5 to 1.0% delayed browning and extended the post-cutting life to seven days at 5°C. Furthermore, fresh-cut banana treated with chemical dip pH 2.5 showed a longer shelf life than pH 7.0, in terms of firmness. This is in contrast with Gorny et al. (2002) who found that a mixture of 2% (w/v) ascorbic acid + 1% (w/v) calcium lactate + 0.5% (w/v) cysteine at pH 7 was more effective in preventing softening of fresh-cut pears than the same mixture at pH 3.7.

Calcium chloride was chosen to be the calcium salt used in the chemical dip of subsequent experiments because calcium lactate promoted yeast growth.

3.2 Effects of chemical dip and/or coating on firmness

Firmness was chosen as the quality indicator parameter for the study of the effects of chemical dip and/or coating. Since the effect of storage on firmness of fresh-cut banana was pronounced during the first two days in the previous experiment with the two calcium salts, the study of the effect of edible coating with or without chemical dip on firmness of banana slices was shortened to three days of storage at 5°C (Table 1).

Table 1 Effects of different chemical dips and edible coatings on firmness of fresh-cut banana after three days of storage at 5°C

<i>Treatment</i>	<i>Firmness</i>				
	<i>Day 0</i>		<i>Day 3</i>		<i>Relative decrease, %</i>
Control	0.64 ± 0.09	b	0.35 ± 0.04	e	47
Dip	0.69 ± 0.09	a	0.46 ± 0.04	c	32
Alginate	0.64 ± 0.10	b	0.53 ± 0.05	b	22
Dip + alginate	0.66 ± 0.09	a	0.56 ± 0.04	ab	16
CMC	0.67 ± 0.10	ab	0.39 ± 0.04	de	42
Dip + CMC	0.68 ± 0.10	ab	0.52 ± 0.04	b	22
Carrageenan	0.67 ± 0.09	ab	0.41 ± 0.04	d	40
Dip + carrageenan	0.67 ± 0.08	ab	0.57 ± 0.06	a	15
Chitosan	0.64 ± 0.09	b	0.46 ± 0.05	c	31
Dip + chitosan	0.65 ± 0.09	b	0.51 ± 0.04	b	24
Pectin	0.68 ± 0.07	ab	0.40 ± 0.03	d	41
Dip+ pectin	0.70 ± 0.10	a	0.53 ± 0.05	b	22

Notes: Dip contains 1% calcium chloride, 0.5% ascorbic acid and 0.75% cysteine. CMC is carboxymethyl cellulose. Different letters in the same column means significantly different ($p < 0.05$).

The loss of firmness in control sample was around 47%, whilst firmness of dipped + coated samples decreased by 15–24% (Table 1). Among the treated samples, coating with CMC, carrageenan and pectin solutions produced the highest relative decrease of firmness (~40%), while dip alone showed 32 % of relative decrease.

The combined effect of the chemical dip (1% CaCl₂, 0.5% ascorbic acid and 0.75% cysteine) and coating, especially with alginate and carrageenan solutions (firmness loss of ~15%), reduced the softening rate compared to the untreated (control), dipped alone and only coated samples.

3.3 Combined effect of chemical dip and coating on firmness and colour

Since coating alone, in general, did not provide protection against firmness losses, another experiment was carried out with dip and dip combined with coating, and the study was extended to five days storage, and it included colour since it is also a critical quality parameter, along with texture. Although dip + chitosan, revealed a good protection against firmness losses (Table 1), it was not further investigated because of poor pre-sensorial analysis (bitter taste).

Table 2 shows that firmness of untreated banana slices decreased significantly during five days of storage, showing a substantial softening of 54%. Among all treatments, dip alone and dip + carrageenan showed the lowest firmness loss (~47%) while dip + pectin was found to have the highest relative decrease (64%).

Table 2 Firmness (N) and L* and chroma values of chemically dipped and coated fresh-cut banana during five days of storage at 5°C

<i>Treatment</i>	<i>Day 0</i>		<i>Day 2</i>		<i>Day 5</i>	
	<i>Firmness (N)</i>					
Control	1.13 ± 0.09	a	0.69 ± 0.06	c	0.51 ± 0.05	c
Dip	1.15 ± 0.10	a	0.78 ± 0.08	a	0.60 ± 0.06	a
Dip+ alginate	1.10 ± 0.11	a	0.73 ± 0.07	b	0.55 ± 0.05	b
Dip+ CMC	1.09 ± 0.10	a	0.57 ± 0.05	d	0.47 ± 0.04	d
Dip + carrageenan	1.11 ± 0.10	a	0.75 ± 0.07	ab	0.58 ± 0.06	a
Dip + pectin	1.12 ± 0.11	a	0.68 ± 0.05	c	0.40 ± 0.04	e
<i>L* value</i>						
Control	69.6 ± 2.0	a	52.2 ± 2.7	d	51.4 ± 2.3	c
Dip	70.8 ± 2.6	a	68.7 ± 1.5	a	60.6 ± 3.4	a
Dip+ alginate	68.8 ± 2.7	a	61.7 ± 2.1	b	49.6 ± 2.8	c
Dip+ CMC	70.6 ± 0.8	a	56.6 ± 2.8	c	49.6 ± 2.8	c
Dip + carrageenan	70.1 ± 1.1	a	56.3 ± 3.3	c	53.1 ± 3.4	b
Dip + pectin	70.0 ± 0.8	a	61.6 ± 2.0	b	47.4 ± 2.6	c
<i>Chroma</i>						
Control	39.5 ± 1.7	a	32.7 ± 1.4	c	30.8 ± 2.1	b
Dip	40.6 ± 1.4	a	36.7 ± 1.3	a	34.7 ± 2.1	a
Dip + alginate	39.5 ± 2.0	a	34.8 ± 2.4	b	27.1 ± 4.0	b
Dip+ CMC	40.3 ± 0.7	a	33.6 ± 3.0	bc	27.5 ± 3.6	c
Dip + carrageenan	40.1 ± 1.5	a	33.2 ± 2.7	c	29.7 ± 2.4	b
Dip + pectin	39.8 ± 1.6	a	36.3 ± 2.3	a	28.3 ± 3.8	c

Notes: Dip contains 1% calcium chloride, 0.5% ascorbic acid and 0.75% cysteine. CMC is carboxymethyl cellulose. Different letters in the same column means significantly different ($p < 0.05$).

Calcium dip makes fruit tissue firmer by reacting with pectic acid in the cell wall to form calcium pectate that strengthens molecular binding between cell wall constituents (King Jr. and Bolin, 1989). Lee et al. (2003) found that edible coating such as carrageenan and whey protein isolate, together with calcium chloride and some other antibrowning agents, can minimise softening of apple slices.

The effect of dip and dip + coating in inhibiting browning was evaluated by monitoring the changes in L* and chroma (C) values during storage (Table 2). Vilas-Boas and Kader (2006) and Abe et al. (1998) evaluated browning of banana pulp by monitoring the decrease of L* values, while Rocha and Morais (2001) used L* and C (along with a*, b* and hue) values to evaluate browning in apples during storage. Lower L* and C values indicate greater browning.

Compared to the control, all five treatments resulted in significantly reduced rates of browning after two days of storage. Dip treated samples showed the highest L* and C during all storage. At the end of storage (five days), they were followed by dip + carrageenan treatment.

Addition of antioxidants such as ascorbic acid, cysteine and 4-hexylresorcinol to coatings like whey protein concentrate-beeswax and carrageenan may reduce browning in fresh-cut apples (Baldwin et al., 1996; Lee et al., 2003; Perez-Gago et al., 2003). On the other hand, Baldwin et al. (1996) reported that CMC based coating did not control enzymatic browning of cut apples and potatoes; but when such coating was combined with additives such as antioxidants, acidulants and preservatives, browning became inferior to the control.

Although chemical dip associated with carrageenan coating can decrease the rate of softening and browning of fresh-cut banana, dip alone had a better efficiency in reducing browning.

3.4 Sensory analysis

The sample that had been dipped in 1% calcium chloride, 0.50% ascorbic acid and 0.75% cysteine received the highest score for colour after five days of storage at 5°C (Table 3). This sample also received better score than the one that had been dipped in the same solution and coated with carrageenan solution for global appreciation and flavour after the same period. However, the highest score obtained was not very high: 3.34.

The sensory results indicated that, taking into account all sensory parameters evaluated, the dipped sample was the only one with edible shelf life of five days at 5°C if the limit of acceptability is set at 3.0.

Table 3 Sensory evaluation of chemically dipped and carrageenan coated fresh-cut banana after five days of storage at 5°C

<i>Treatment</i>	<i>Global appreciation</i>	<i>Colour</i>	<i>Odour</i>	<i>Texture</i>	<i>Flavour</i>
Control	2.73 ± 0.84ab	2.17 ± 0.86b	3.07 ± 0.91a	2.85 ± 0.92a	2.88 ± 1.12ab
Dip	3.21 ± 1.13a	3.01 ± 0.99a	3.23 ± 1.24a	3.23 ± 1.05a	3.34 ± 1.17a
Dip+ carrageenan	2.57 ± 0.81b	2.29 ± 0.87b	2.69 ± 0.93ab	2.66 ± 0.92ab	2.53 ± 0.96b

Notes: Dip contains 1% calcium chloride, 0.5% ascorbic acid and 0.75% cysteine.

Different letters in the same column means significantly different ($p < 0.05$).

4 Conclusions

The combined effect of chemical dips and/or edible coatings on fresh-cut banana was investigated.

Dip containing 1% (w/v) calcium chloride (CaCl_2), 0.50% (w/v) ascorbic acid and 0.75% (w/v) cysteine and dip containing 2% (w/v) calcium lactate, 0.50% (w/v) ascorbic acid and 0.75% (w/v) cysteine were found to have same firming effect on fresh-cut banana during four days of storage at 5°C. However, the latter dip solution was found to cause pinking and yeast growth. Compared with dip with calcium chloride + coating, control and coating alone, in general, presented higher rates of browning and softening after three days storage. Carrageenan solution revealed itself the best coating, among the ones studied, in preserving firmness and colour of fresh-cut banana during five days at 5°C. Dip with 1% (w/v) CaCl_2 , 0.50% (w/v) ascorbic acid and 0.75% (w/v) cysteine was the most efficient treatment in retarding softening and browning of this produce. According to sensory analysis, the edible shelf life of banana slices dipped in such solution was the longest: five days at 5°C.

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