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Effects of edible chitosan coating on quality and shelf life of sliced mango fruit

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Abstract

Mango pulp is very perishable and so has a short shelf life, which both marketers and consumers would like to be longer. Manually sliced mango was treated with aqueous solutions of 0%, 0.5%, 1% or 2% chitosan; placed into plastic trays, and over-wrapped with PVDC film and then stored at 6 °C. Changes in the sensory qualities of taste, color and water loss, were evaluated. A chitosan coating retarded water loss and the drop in sensory quality, increasing the soluble solid content, titratable acidity and ascorbic acid content. It also inhibited the growth of microorganisms. The data reveal that applying a chitosan coating effectively prolongs the quality attributes and extends the shelf life of sliced mango fruit.

Keywords: Chitosan coating; Mango fruit; Quality; Shelf life; Minimally processed fruit

1. Introduction

Mango (*Mangifera indica* L.) fruit is a climacteric fruit with a high commercial value on the international fruit market (Baldwin et al., 1999). Restaurants and consumers like sliced mango for convenience of serving and consumption. However, minimally processed foods are typically stored between 4 and 8 °C (Wiley, 1994). Whole mango fruits exhibit chilling injuries if stored at temperatures of under 13 °C for several days (Acosta et al., 2000) and sliced mango fruit are very perishable because they lack protective pericarp (Tovar, Garcia, & Mata, 2001). Additionally, the pulp is very vulnerable to dehydration, color breaking to dark and disease (Baldwin et al., 1999). External and internal qualities are crucial to consumer acceptability, and an important marketing consideration. Hence, alternative methods are needed for preserving the quality attributes of the flesh of sliced mango during handling, distribution and retail sale.

Minimally processed fruits (MPF) and vegetables contain living tissue that has undergone minor changes from its fresh state. The cutting or splicing operation forms a lesion in the tissue (Tovar et al., 2001). MPF have a shorter shelf life than whole fruits and vegetables, partially because of the physiological changes that occur in wounded viable tissue (Baldwin, Nisperos-Carried, & Baker, 1995). The post-harvest physiology and maintenance of the quality of freshly cut fruit have been studied for kiwifruit, banana, peach, apple, melon (Kader & Gorny, 1998), strawberries, (Palmer & Kader, 1997), halved papaya (Paull & Chen, 1997), pear cubes (Pittia, Nicoli, Comi, & Massini, 1999) and mango slices immersed in $CaCl_2$, citric acid, H_2O_2 and sodium benzoate (Tovar et al., 2001). However, consumers around the world demand high-quality food, without chemical preservatives so an increased effort has been made to discover new natural preservatives and antimicrobials. Therefore, the fungistatic effects of chitosan have been studied (Tripathi & Dubey, 2004).

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Edible coatings have the potential to improve the quality and to extend the shelf life of lightly processed produce (Li & Barth, 1998). Chitosan has been successfully used as a food wrap because of its film-forming properties (Shahidi, Arachchi, & Jeon, 1999). It has thus been used to maintain the quality of post-harvest fruits and vegetables, as examined by Du, Gemma, and Iwahori (1997), El Ghaouth, Arul, Ponnamapalam, and Boulet (1991), El Ghaouth, Ponnamapalam, Castaiglne, and Arul (1992), Ippolito, El Ghaouth, Wilson, and Wisniewski (2000), Jiang and Li (2001) and Zhang and Quantick (1997). Additionally, advantageous effects of the extension by chitosan coatings of the storage life of freshly cut Chinese water chestnut were identified by Pen and Jiang (2003) and those of freshly peeled litchi were investigated by Dong, Cheng, Tan, Zheng, and Jiang (2004). Given the perishability of mango and its importance in global commercial agriculture, polysaccharide-based and carnauba wax coatings have been reported to reduce markedly water loss, and to extend its shelf life (Baldwin et al., 1999), verifying that polysaccharide coatings are less permeable than carnauba wax coatings to respiratory gases such as O_2 (Baldwin et al., 1999).

To the authors' knowledge, no scientific literature covers the use of chitosan coating to maintain the quality and extend the shelf life of freshly sliced mangoes. Therefore, the aim of this work is to elucidate the effects of chitosan coating on quality and shelf life of sliced mango fruit.

2. Materials and methods

2.1. Plant materials

The mango (*Mangifera indica* L.) cv. Irwin was used in the experiment was grown in Yujing, Tainan, Taiwan, and brought to the laboratory immediately after it was harvested. The fruit were selected for their uniformity, size, color, shape, and absence of damage and fungal infection. The 60 fruits were separated into groups of three, for treatment in triplicate. Following washing, the fruit were peeled manually, and sliced into volumes of $5 \times 4 \times 1$ cm. They were dipped for 1 min into a solution of 0% (control), 0.5%, 1% or 2% chitosan (95–98% deacetylated and viscosity $\leqslant$30 mPa s; VA&G Bioscience Inc., Taoyuan, Taiwan). Thus, prepared as described by Jiang and Li (2001). 0, 5.0, 10.0 or 20.0 g of chitosan was dispersed in 900 ml of distilled water to which 50 ml of glacial acetic acid was added to dissolve the chitosan, to prepare 1.0 L of 0%, 0.5%, 1% or 2% chitosan solutions. The pH of the solution was adjusted to pH 5.0 with 0.1 M NaOH and the solution was made up to 1.0 L. An acid solution at pH 5.0, without chitosan was used as a control. After they had been air-dried for 30 min at 25 °C, the sliced fruit were placed into plastic trays, and over-wrapped with 30×20 cm PVDC film (Wu-Yu Chimistry Co., Japan). They were then stored at 6 °C to be later assessed. Mango fruit pulp stored at 6 °C had the best quality (unpublished data), so this temperature was used in this work.

All other chemicals were obtained from commercial sources and were of analytical grade.

2.2. Determining weight loss and moisture content

Three batches of 100 slices underwent each treatment. Ten slices were removed from each treatment daily. The slices were weighed regularly to determine weight loss, which was calculated cumulatively by comparing the weights of fruit immediately after slicing, treatment with chitosan and air-drying for 30 min after various storage times, and expressing the results as percentages. The moisture content was determined by the AOAC method (1984).

2.3. Measuring amounts of soluble solids, titratable acidity and ascorbic acid

The mango pulp was dipped in 0.5%, 1% or 2% chitosan solutions. The control sample was dipped into acid solution without chitosan at pH 5.0. Three identical groups of 100 slices underwent each treatment. After each day in storage, 10 slices were removed from each group and the amount of soluble solids, the titratable acidity and the ascorbic acid content of the fruit pulp were determined. Pulp (25 g) from 10 slices was homogenized using a grinder and then centrifuged at 3500 rpm (Du-Pont, model Sorvall RC-5C) for 20 min. The supernatant phase was collected and analyzed to determine the amount of soluble solids, using a hand refractometer (ATAGO, model N1); the titratable acidity and ascorbic acid content were determined by titration with 0.1 M NaOH, and the ascorbic acid content was determined by 2,6-dichlorophenolindorhenol titration (AOAC, 1984).

2.4. Color analysis

A CIELAB colorimetry system was used to determine the color. Coloration was determined using a Color-Pen™ handy color difference photometer (Dr. Bruno Lange GmbH, Berlin, Germany), which recorded the spectrum of reflected light and converted it into a set of color coordinates (L, a and b values). Color 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 ($X = 83.6$, $Y = 81.2$, $Z = 93.8$) and a black plate were used to standardize the instruments.

2.5. Microbiological analysis

The microbiological characteristics of a 10 g sample were obtained after homogenization in 90 ml 0.1% peptone water (Difico, 0118-17-0). Other decimal dilutions were prepared from a 10^{-1} dilution. The total count was determined using the pour plate method, and Plate Count Agar

(Difco, 0479-17) as the medium. Plates were incubated at 35 °C for 48 h (Harrigan & McCance, 1976).

Three samples in each group were analyzed. All counts were presented as average values over three samples.

2.6. Evaluating sensory quality

The sensory quality of each replicate pulp was evaluated by visual appearance, taste, flavor and acceptability. Samples of fruit pulp were presented in random order to 15 panelists for sensory evaluations. They were rated on a nine-point hedonic scale (9, excellent; 7, very good; 5, good; 3, fair and 1, poor) for visual appearance, sweetness, sourness, off-flavor and overall flavor; intensity and acceptability increased with the numerical value.

2.7. Statistical analysis

The data from the repeated experiments were analyzed to determine whether the variances were statistically homogeneous. Each sample was analyzed three times and each experiment was conducted in triplicate ($n = 3$). The results were expressed as means ± SE. Statistical comparisons were made by one-way analysis of variance (ANOVA) followed by a Dunnett multiple comparisons test. Differences were considered to be significant when the p-values were under 0.05.

3. Result

3.1. Sensory evaluation

Both the taste and the color scores of mango pulp fell quickly during storage. Chitosan coating delayed the drop in sensory quality, and extend the shelf life. Both the control and the chitosan-coated, sliced mango fruit were still commercially satisfactory after they had been stored for three days. However, they had been stored for seven days, the control became unacceptable for the market whereas the good quality of the chitosan-coated sliced fruit was retained. The sensory quality after three days did not vary among the fruit treated with 0.5%, 1% and 2% chitosan but the difference between the quality following treatment with 1% and 2% chitosan after seven days was significant (Table 1). Dong et al. (2004) reported that chitosan coating improved the quality and extended the shelf life of peeled litchi fruit. In this work, the chitosan coating on sliced mango improved its quality and prevented surface cracking and the leaking of juice.

3.2. Weight loss and moisture content

A chitosan coating retarded the weight loss of sliced mango fruit (Table 1). After seven days of storage, the weight losses of the control and 2% chitosan-coated sliced mango were 19.86% (highest) and 10.27% (lowest), respectively. The great weight was lost mainly by the leakage of juice from the pulp, rather than by the loss of water. Therefore, one of advantageous effect of chitosan coating on the loss of weight by mango pulp was protection by reducing the leakage of juice. Additionally, significant differences between 0.5% and 1% or 2% chitosan were observed at the $p < 0.05$ level, when the fruit were stored for three, five or seven days at 6 °C.

Table 1
Effect of chitosan coating on sensory quality, weight loss and water content of sliced mango stored at 6 °C

Chitosan (%)	Sensory quality	Weight loss (%)	Water contents (%)
Before treatment			
0.0	9.0	0	88.03 ± 1.06
0.5	9.0	0	88.03 ± 1.06
1.0	9.0	0	88.03 ± 1.06
2.0	9.0	0	88.03 ± 1.06
Three-day storage			
0.0	7.25 ± 0.11^a	7.95 ± 0.31^a	80.64 ± 0.08^c
0.5	8.15 ± 0.20^a	5.92 ± 0.29^b	82.31 ± 0.56^b
1.0	8.29 ± 0.12^a	3.35 ± 0.16^c	85.24 ± 0.45^a
2.0	8.21 ± 0.13^a	3.32 ± 0.17^c	85.69 ± 0.62^a
Five-day storage			
0.0	5.19 ± 0.23^c	15.24 ± 0.52^a	73.67 ± 1.26^c
0.5	6.27 ± 0.30^b	12.61 ± 0.58^b	78.26 ± 0.59^b
1.0	7.38 ± 0.33^a	7.23 ± 0.32^c	82.50 ± 1.01^a
2.0	7.22 ± 0.27^a	6.98 ± 0.34^c	82.98 ± 1.18^a
Seven-day storage			
0.0	3.85 ± 0.12^c	19.86 ± 0.85^a	70.88 ± 2.33^c
0.5	5.79 ± 0.28^b	16.42 ± 0.73^b	73.34 ± 1.01^b
1.0	6.42 ± 0.27^a	11.06 ± 0.48^c	78.53 ± 1.15^a
2.0	6.02 ± 0.10^b	10.27 ± 0.50^c	78.80 ± 1.19^a

Means are averaged values of three trials. Each trial contained three replicates of 20 sliced mangoes each per treatment. Quality was evaluated after seven days of storage at 6 °C.
Values within a column with the same letter are not significantly different ($p > 0.05$).

3.3. Total soluble solids, titratable acidity and ascorbic acid

The total soluble solid content, the titratable acidity and the ascorbic acid content of sliced mango fruit fell greatly after seven days of storage (Table 2). The sliced fruit that had been treated with chitosan had a greater total soluble solid content, titratable acidity and ascorbic acid content, but the total soluble solid contents did not vary significantly among the fruit treated with 0.5%, 1% and 2% chitosan.

3.4. Analyzing color

Table 3 reveals that chitosan-coated sliced mangoes exhibited significant changes in the L value during storage. The L values of the fruit treated with 0.5%, 1% and 2% chitosan did not vary significantly after seven days (Table 3), indicating that chitosan-coated sliced mango underwent changes in lightness.

Table 2
Analyses of chitosan coating on sliced mango after seven days of storage at 6 °C

Chitosan (%)	Total soluble solids (°Brix)	Titratable acidity (%)	Ascorbic acid (mg/100 ml)
Before treatment	13.10 ± 0.52^{a}	0.80 ± 0.03^{a}	25.02 ± 1.20^{a}
After storage			
0.0	11.87 ± 0.30^{c}	0.67 ± 0.03^{c}	16.29 ± 0.80^{d}
0.5	12.23 ± 0.36^{b}	0.69 ± 0.02^{c}	19.92 ± 0.91^{c}
1.0	12.36 ± 0.31^{b}	0.75 ± 0.03^{b}	22.13 ± 1.10^{b}
2.0	12.28 ± 0.32^{b}	0.68 ± 0.03^{c}	20.87 ± 0.85^{c}

Means are averaged values of three trials. Each trial contained three replicates of 20 sliced mangoes each per treatment. Quality was evaluated after seven days of storage at 6 °C.
Values within a column with the same letter are not significantly different ($p > 0.05$).

Table 3
Effect of chitosan coating on color of sliced mango during storage at 6 °C

Chitosan (%)	*L* values	*a* values	*b* values
Before treatment			
0.0	66.76 ± 1.09	10.27 ± 0.56	15.37 ± 0.31
0.5	66.76 ± 1.09	10.27 ± 0.56	15.37 ± 0.31
1.0	66.76 ± 1.09	10.27 ± 0.56	15.37 ± 0.31
2.0	66.76 ± 1.09	10.27 ± 0.56	15.37 ± 0.31
Three-day storage			
0.0	57.86 ± 1.06^{c}	12.72 ± 0.41^{a}	15.17 ± 0.21^{a}
0.5	63.48 ± 0.93^{a}	10.38 ± 0.25^{b}	14.69 ± 0.50^{a}
1.0	64.95 ± 1.15^{a}	10.33 ± 0.33^{b}	14.73 ± 0.46^{a}
2.0	65.02 ± 0.98^{a}	10.25 ± 0.42^{b}	15.11 ± 0.13^{a}
Five-day storage			
0.0	56.87 ± 0.99^{c}	13.12 ± 0.30^{a}	14.87 ± 0.25^{a}
0.5	61.52 ± 1.04^{b}	11.02 ± 0.22^{b}	15.02 ± 0.23^{a}
1.0	61.60 ± 0.96^{b}	10.61 ± 0.41^{b}	14.72 ± 0.16^{a}
2.0	61.85 ± 1.09^{b}	10.67 ± 0.39^{b}	14.99 ± 0.20^{a}
Seven-day storage			
0.0	56.64 ± 1.02^{c}	13.25 ± 0.28^{a}	14.62 ± 0.13^{a}
0.5	61.25 ± 1.06^{b}	11.13 ± 0.17^{b}	14.93 ± 0.10^{a}
1.0	61.37 ± 1.01^{b}	10.91 ± 0.36^{b}	14.85 ± 0.22^{a}
2.0	61.46 ± 1.14^{b}	10.93 ± 0.28^{b}	15.04 ± 0.18^{a}

Means are averaged values of three trials. Each trial contained three replicates of 20 sliced mangoes each per treatment. Colour values was evaluated after seven days of storage at 6 °C.
Values within a column with the same letter are not significantly different ($p > 0.05$).

Table 3 presents the evolution of the redness of the control and chitosan-coated sliced mango fruit. Before storage, all samples had an *a* value of approximately 10.27 ± 0.56. The *a* value of both the control and the chitosan-coated sliced mangoes rose continuously ($p < 0.05$). This increase in the redness was probably caused by an increase in the respiration rate and the promotion of enzymatic processes that were responsible for a drop in quality of the fruit, which involved browning and other reactions. The *a* value associated with chitosan treatment was lower than that of the control, but did not change significantly after three treatments with 0.5–2% chitosan ($p > 0.05$). The *b* (yellowness) values of all samples (coated and uncoated) were unchanged after storage.

The color of sliced mango fruit is importantly determines consumer acceptance, and although a chitosan coating did not change the original color of the fruit, it did delay browning.

3.5. Microbiological analysis

Table 4 presents the results of the microbiological analysis of chitosan-coated and uncoated, sliced mango fruits. The total number of uncoated samples increased from 3.82, through 4.23, 4.54, 4.98, 5.19, 5.95 and 6.12–6.41 log CFU/g at the end of the storage. The chitosan coating on the sliced mango effectively inhibited the growth of microorganisms, but increasing the concentration of chitosan from 0.5% to 2% did not further affect the growth of microorganisms (Table 4).

4. Discussion

Sensorial analysis revealed that chitosan-coated samples were superior at the end of a seven-day holding period. The coating did not change affect the natural taste of sliced mangoes, which fact is important since is undesirable. The color characteristics of the chitosan-coated samples did not differ from those of the blank. Additionally, chitosan-coated, sliced mango fruits exhibited slower decay and lower water loss.

In conclusion, the maintenance of quality and the extension of the shelf life of sliced mango fruit by chitosan coating, presented here, reveals that such a coating can be considered for commercial application during storage and marketing.

Table 4
Effect of chitosan coating on microbiological changes of sliced mango stored at 6 °C

Chitosan (%)	Log CFU/g							
	0 day	1 day	2 days	3 days	4 days	5 days	6 days	7 days
0.0	3.82	4.23^{a}	4.54^{a}	4.98^{a}	5.19^{a}	5.95^{a}	6.12^{a}	6.41^{a}
0.5	3.82	3.99^{b}	4.25^{b}	4.48^{b}	4.70^{b}	5.13^{b}	5.39^{b}	5.53^{b}
1.0	3.82	3.92^{b}	4.23^{b}	4.40^{b}	4.58^{b}	5.03^{b}	5.22^{b}	5.41^{b}
2.0	3.82	3.90^{b}	4.19^{b}	4.28^{b}	4.36^{b}	4.99^{b}	5.19^{b}	5.30^{b}

Means are values averaged over three trials ($n = 3$; mean value ± standard deviation). Each trial involved three identical groups of 20 sliced mangoes per treatment. Microbiological analysis was conducted during seven days of storage at 6 °C.
Values within a column with the same letter are not significantly different ($p > 0.05$).

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