Influence of chitosan coatings with citric essential oil on the shelf-life of minimally processed mango (*Mangifera indica* L.)

Influencia de recubrimientos de quitosano con aceites esenciales de cítricos sobre la vida útil de mango (*Mangifera indica* L.) mínimamente procesado

Fabián Rico Rodríguez[1]; Carolina Gutiérrez Cortés[2] and Consuelo Díaz Moreno[3]

Abstract. *Demand for minimally processed fruits have increased due to their nutritional value and an increasing change in consumption habits. Physicochemical, microbiological, structural and sensory changes were determined in minimally processed mangoes (MPM) with chitosan (CH) edible coatings and lemon and orange essential oils (EOL). The MPM was first dipped in citric acid and a texturizing solution and then dipped in CH and lemon or orange EOL coatings. Weight loss, sensory acceptance, total soluble solids, total acidity, ascorbic acid, color changes, firmness and elasticity, and microbiological changes were quantified for 11 days of refrigerated storage. The CH and lemon EOL coating had more acceptance than the other treatments. No differences were found (p>0.05) for weight loss, total acidity, ascorbic acid, firmness or elasticity. There was a high amount of total phenols due to the EOL composition, as well as a high antioxidant capacity in the early days of storage. This characteristic decreased in the final days of the study. There was a decrease in the microbial charge for the lemon EOL treatment, as compared to the other samples. The CH and lemon EOL coating helped to maintain the shelf-life of the MPM for 11 days of storage without affecting the sensory acceptance. The CH and Orange EOL coating did not have an effect on the MPM physicochemical attributes; however, the sensory acceptance was negatively affected with off-flavors conferred to the MPM.*

Key words: Edible coating, shelf-life, biopreservation, minimally processed fruits.

Resumen. *Las frutas mínimamente procesadas han aumentado su demanda debido al cambio en los hábitos de consumo y al valor nutricional de estos alimentos. Fueron determinados los cambios fisicoquímicos, microbiológicos, estructurales y sensoriales en mango mínimamente procesado (MPM) con recubrimientos comestibles de quitosano (CH) y aceites esenciales (EOL) de limón y naranja. El MPM fue previamente inmerso en ácido cítrico y solución texturizante, bañado con recubrimiento de CH y EOL de limón o naranja. Se cuantificó pérdida de peso, aceptación sensorial, sólidos solubles, acidez titulable, ácido ascórbico, fenoles totales y capacidad antioxidante, cambios de color, firmeza y elasticidad y crecimiento microbiano durante 11 días de almacenamiento refrigerado. El recubrimiento de CH y EOL de limón tuvo mejor aceptación que los otros tratamientos. No se encontraron diferencias (p>0,05) en pérdida de peso, acidez titulable, ácido ascórbico, firmeza o elasticidad. Se encontró un alto contenido de fenoles totales debido a la composición de los EOL, de igual manera una alta capacidad antioxidante durante los primeros días de almacenamiento. Esta característica disminuyó a lo largo de los días de estudio. La carga microbiana para el tratamiento con EOL de limón fue más baja al final del tiempo de estudio comparado con las demás muestras. El recubrimiento de CH y EOL de limón ayuda a mantener la vida útil del MPM por 11 días de almacenamiento refrigerado sin afectar la aceptación sensorial. El recubrimiento con CH y EOL de naranja no afectó los parámetros fisicoquímicos del mango, sin embargo, fue rechazado debido a los sabores que confería al MPM.*

***Palabras claves*:** Recubrimiento comestible, vida útil, biopreservación, frutas mínimamente procesadas.

Fresh-cut product or minimally-processed product consumption is a trend with great acceptance worldwide (Oms-Oliu *et al*., 2010). Minimally processed products are fruits and vegetables which have been washed, peeled, cut and packed to provide "Ready-to-eat" foods with similar attributes as fresh products (Florkowski *et al*., 2009; Panadés *et al*., 2008). Treatments, handling and environmental exposure make minimally processed products very perishable (Florkowski *et al*., 2009). Mango (*Mangifera indica* L.) is an important product in the international trade of foods due to its juiciness, texture, sweetness, exotic flavor and sensory acceptance. These attributes are very attractive to fruit customers. Mango is consumed in different maturity stages and presentations (juice, sauce, jam) (Machado and Schieber, 2010; Materano *et al*., 2004). Colombia has natural conditions for producing high quality mango although techniques for its cultivation, harvest and postharvest are required (Cartagena and Vega, 2001). For example, losses of about 25% have been reported during postharvest (Tafur *et al*., 2006).

Packaging techniques play an important role in food quality and shelf-life because they confer the ability to

[1] Estudiante, Doctorado Ingeniería Química. Universidad Nacional de Colombia - Sede Bogotá- Facultad de Ingeniería. Carrera 30 No 45A-03, Bogotá, Colombia. <faricoro@unal.edu.co>
[2] Estudiante. Doctorado Biotecnología. Universidad Nacional de Colombia - Sede Bogotá- Instituto de Biotecnología. Carrera 45 No 26-85, Bogotá, Colombia. <cgutierrezco@unal.edu.co>
[3] Profesor Asociado. Universidad Nacional de Colombia - Sede Bogotá - Instituto de Ciencia y Tecnología de Alimentos -ICTA. A.A. 034227, Bogotá, Colombia. <madiazmo@unal.edu.co>

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carry antimicrobial substances (active packaging) to different food products and have the ability to protect the contents (Dutta *et al*., 2009; Sánchez-González *et al*., 2011). In order to achieve this purpose, many natural compounds have been studied with a polymeric matrix (Sánchez-González *et al*., 2011). An example of this is chitosan (CH), a polysaccharide obtained from animal sources that is commonly used in edible film and coating development (Muzzarelli *et al*., 2012). CH is widely used in active systems due to its characteristics, such as biodegradability, non-toxicity and antimicrobial activity against bacteria, yeasts and molds (Embuscado and Huber, 2009; Falguera *et al*., 2011; Nussinovitch, 2009).

Additionally, essential oils (EOL) are aromatic compounds produced as secondary metabolites from aromatic plants (Bakkali *et al*., 2008). EOLs have an antimicrobial capacity (Bajpai *et al*., 2011); particularly citric EOL, which has great potential for food preservation. Its *in vitro* antimicrobial activity has been proven against *Escherichia coli, Staphylococcus aureus* and *Salmonella* sp. (Sánchez-González *et al*., 2010, 2011).

In fruits such as fresh-cut mangoes (Chien *et al*., 2007) and strawberries (Fernandez-Saiz *et al*., 2008) and in vegetables such as carrots (Vargas *et al*., 2009), a delayed moisture loss and a decreased sensory acceptance were obtained using a coating made of different concentrations of CH. In addition, the use of these coatings increased characteristics such as soluble solids content, titratable acidity and ascorbic acid content. As a consequence, the shelf-life was extended.

The demand for shortened processing times or "ready -to-eat" foods has increased in recent decades. In addition, interest in consuming foods with the nutritional and sensory characteristics of fresh food has also gained importance (Oms-Oliu *et al*., 2010). In spite of their properties, minimally processed fruits have a short shelf-life, making storage and preservation difficult and increasing biochemical changes after postharvest operations (Arias *et al*., 2007).

The aim of this research was to evaluate the physicochemical, microbiological, structural and sensorial parameters of MPM with CH edible coatings with lemon and orange EOLs.

MATERIALS AND METHODS

Plant materials. The mango cv *T*ommy Atkins used in this experiment was selected according to size and weight (over 300 g). Absence of injuries and fungal diseases were taken into account as selection parameters. Then, the mangoes were classified according to CODEX-STAN 184 sanity and quality parameters (Codex alimentarius, 1993) and sanitized. They were peeled and cut into 1 cm cubes and dipped for 10 minutes in a citric acid solution (1.0 %w/v). Finally, they were dipped for 1 minute in calcium chloride (0.5% w/v) as a texturizing substance.

Coatings. CH (Kittoflo® - Oslo, Norway) and EOL (Aromasynt SAS – Bogota, Colombia) solutions were prepared according to Sánchez-González *et al.* (2011) with some modifications. CH (2 %w/v) was dissolved in a lactic acid solution (1 %v/v) at 40°C for 2 h, filtered and mixed with glycerol (1 %v/v). An orange or lemon EOL was emulsified in concentrations of 1.0 %v/v and stirred at 800 rpm for 3 h. Afterwards, it was degasified at 25°C and stored until the assays were carried out.

Treatments. The previously prepared MPM was separated into four treatments (C0 = Control sample, CQ = sample with chitosan, CL = sample with chitosan and lemon essential oil and CN = sample with chitosan and orange essential oil). Polypropylene glasses were filled with 120 g of MPM previously dipped in a solution treatment (1:1 ratio) for 1 min and drained. The treatments were stored at refrigeration temperatures (5°C) until sampling and analysis. Analyses were carried out every three days over 11 days.

Weight loss determination. A sample of each treatment was taken daily and weighed regularly to determine weight loss for 11 days. Every value was compared with the original weight of the fruit immediately after slicing, according to the procedure described by Chien *et al.* (2007). Determinations were made in triplicate.

Total soluble solids, total acidity and ascorbic acid content. The MPM total soluble solids were measured for 11 days according to procedure 932.15 (AOAC, 2002), using a hand refractometer (ATAGO® - Fukaya, Japan). Pulp from cubes was homogenized using a blender and then centrifuged at 3500 rpm for 20 min. Total acidity was measured with 10 g of supernatant diluted in distilled water and 0.3 mL of phenolphthalein solution. Then, this solution was titrated with NaOH 0.1 M. The ascorbic acid content was measured by spectrophotometry (Ryley and Kajda, 1994). 1 g of pulp of each treatment was homogenized in an oxalic acid solution (0.15 %w/v) and filtered. Then, 100 µL of 2-nitroaniline 0.16 %w/v (HCl and Acetic acid 1:1 solution) were added to 1 mL of the supernatant. Later, 100 µL of sodium nitrite (0.08 %w/v) were added, stirring until decoloration and stored for 5 min. Subsequently, 3.6 mL of absolute ethanol and 1 mL of NaOH (10 %w/v) were added. Absorbance was measured at 534 nm. Determinations were made in triplicate.

Color. The color variation of the samples was measured using a colorimeter (MINOLTA CR300® - New Jersey, USA) based on CIELAB color parameters in which, *L** defines lightness and *a** and *b** are two chromatic components that range between green and red, and blue and yellow, respectively (Chiumarelli *et al*., 2011; Djioua *et al*., 2009). Determinations were made in triplicate.

Firmness and elasticity. The MPM firmness and elasticity were evaluated using a Texas TA-TX texturometer to penetrate the MPM surface. The samples were held perpendicular to the probe. The operating conditions were: speed-in 1.0 mm s^{-1}, penetration speed 2.0 mm s^{-1}, depth 6.0 mm and speed-out 10 mm s^{-1}.

Total phenols and antioxidant capacity. 10 g of MPM were homogenized and extracted in 20 mL of ethanol:acetone (7:3 v/v) for 1 h at room temperature. The extract was filtered and washed with ethanol:acetone (70:30). This procedure was repeated twice to obtain the maximum extraction. The solution was stored at -20°C until used for analysis. The total phenols were determined according to the Folin-Ciocalteau method with Gallic acid as the patron (Liu *et al*., 2013). The extracts were mixed with 2 mL of Folin–Ciocalteau reagent and, after reacting for 1 min, 1.8 mL of 7.5% Na2CO3 solution were added with further storage for 2 hours. The mixture was measured at 765 nm using a spectrophotometer (THERMO®). The total phenols were expressed as mg L^{-1} equivalents of gallic acid (EAG). The antioxidant capacity by ferric reducing ability power (FRAP) was measured as described by Ma *et al.* (Ma *et al*., 2011) for fresh mango samples. The stock solutions were prepared with 300 mM acetate buffer at a pH of 3.6, 10 mM TPTZ solution in 40 mM HCl and 20 mM $FeCl3{\cdot}6H_2O$ solution (10:1:1). 25 µL of Trolox were added to 1 mL of distilled water, allowing it to react with 1.8 mL of FRAP solution for 30 min at room temperature. Absorbance was measured at 593 nm. The results were expressed in mM Trolox/kg fresh weight. Determinations were made in triplicate.

Microbiological analysis. The microbiological characteristics of the MPM stored for 11 days were measured according to INVIMA procedures (Holguin *et al*., 1998). 10 g of sample were homogenized in 90 mL of peptone water 0.1% (Oxoid® - Ontario, Canada). Decimal dilutions (10^{-2} and 10^{-3}) were prepared from 10^{-1} dilution. Total and fecal coliforms were performed using BRILA broth (Merck® – Ney Jersey, USA), tryptophan broth (Oxoid® - Ontario, Canada) and EMB agar (Merck® – Ney Jersey, USA). Incubations were carried out for 48 h at 37°C for total coliforms, while 48 h at 43°C were used for fecal coliforms. Mesophilic and psychrophilic bacteria were numbered using plate count agar (Merck® – New Jersey, USA) and incubated for 48 h at 37°C and 5 d at 5°C, respectively. Molds and yeasts were grown in OGY agar (Oxoid® - Ontario, Canada) with Oxitetracycline and incubated for 5 days at 25°C.

Sensory evaluation. The sensory acceptance of the MPM with CH and EOL coatings was evaluated by visual appearance, taste, flavor and general acceptability through an affective test with 60 consumer panelists. MPM with CH coatings and lemon (CL) or orange (CN) EOL samples were prepared; moreover, samples with CH coating (CQ) and no coating (control – C0) were randomly presented to the panelists. The samples were rated on a five-point hedonic scale (5, I like very much; 3, good; 1, I dislike very much). Intensity and acceptability increased with numerical values.

Statistical analysis. The results were analyzed statistically by analysis of variance (ANOVA) using Statistix® 8.0 software. The mean separation was determined using the Tukey test at $p<0.05$. For the sensory evaluation, a Kruscal-Wallis design was used at a significant level of 0.05.

RESULTS AND DISCUSSION

Weight loss. The weight loss percentages for the first three days of storage were the highest of this study for all treatments (Figure 1). Subsequent days exhibited a constant trend with small increases at the end of the assay. However, the CL and CN coatings slowed and reduced weight loss in the mango samples, as compared with the control (C0). This reduction was related to biochemical reactions associated with ripening of mango, in which water is a metabolic product (Muda *et al*, 1995). Significant differences between the treatments ($p>0.05$) were found: weight loss in the C0 was higher than those presented in the CQ or CH-EOL treatments. These results are in agreement with Chien *et al.* (2007), who found that CH coatings act as a barrier to water in sliced mango. Similarly, Sarsi-de-Souza *et al.* (2006) found an increase in weight loss when combining citric acid and calcium treatments in sliced mango, which explains why C0 had the highest weight lost.

Total soluble solids, total acidity and ascorbic acid
Table 1 shows variation of the total soluble solids (%) of the MPM with coatings during refrigerated storage. No significant differences (p>0.05) were found among the samples. As expected, storage time played an important role for each sample. CQ kept total solids constant at 8.4% during storage. Moreover, the treatments including EOLs (CN and CL) had a slight increase in total solids. During storage, the control showed a decrease in the total soluble solid content. According to other authors (Hoa and Ducamp, 2008; Sothornvit and Rodsamran, 2008; Tovar *et al*., 2001a, 2001b), total solids tend to increase at fruit ripening.

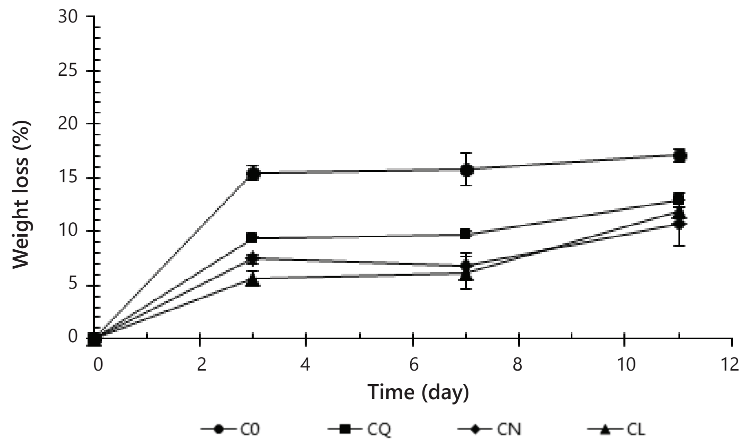

Figure 1. Weight loss (%) in samples of minimally processed mango (without coating (C0), with chitosan coating (CQ), with chitosan and orange (CN) and lemon (CL) essential oils).

This behavior is also related to weight loss. The C0 had the highest weight reduction, as well as a reduction of soluble solids. For the other treatments, the coatings reduced the weight and total soluble solids losses. For total acidity (Figure 2a), CL showed the highest decrease during storage (from 0.65 g/100 g to 0.49 g/100 g). The other samples had a constant tendency of total acidity. Statistical differences (p>0.05) were not found between the treatments. The acidity values were in the same range of those reported by Chien *et al*. (2007) (from 7.0 to 11.06% of weight loss). The ascorbic acid content (Figure 2b) had the most significant variation for C0 (4.4 mg/100 g). The ascorbic acid showed much lower values than those reported by Chien *et al*. (2007), which ranged from 25.02 mg/100 mL to 16.29 mg/100 mL. However, the ascorbic acid content in other studies have shown values much lower (11 mg/ 100g to 5 mg/ 100 g) than in the present study (Djioua *et al*., 2009) although the values were not significantly different from each other (p>0.05). This variation can be related to oxidation processes during MPM storage, indicating an antioxidant effect from CH and EOLs coatings.

Table 1. Total soluble solids (%) of minimally processed mango with chitosan and essential oils coatings.

Sample	Day 0	Day 3	Day 7	Day 11
C0	7.87 ± 0.42 a	7.73 ± 0.64 a	7.67 ± 0.58 a	7.67 ± 0.61 a
CQ	8.33 ± 0.64 b	8.47 ± 0.58 b	8.40 ± 0.72 b	8.40 ± 0.80 b
CN	7.67 ± 0.31 a	7.80 ± 0.20 a	7.87 ± 0.46 a	8.07 ± 0.31a
CL	7.67 ± 0.31 a	7.73 ± 0.23 a	7.73 ± 0.23 a	7.93 ± 0.12 a

MPM without coating (C0), with chitosan coating (CQ), with chitosan and orange (CN) and lemon (CL) essential oils.
Values with the same letter within the column are not significantly different.

Color. Table 2 shows color parameters of the MPM with coatings during 11 days of storage. A statistical analysis revealed no significant differences (p>0.05) for *L** and *b**. However, the *a** parameter was significantly different

(P<0.05) for CQ which had the biggest change tending to redness. This parameter is related to MPM respiratory rates, specifically with enzymatic browning. This variation indicates that the CQ treatment had a low or poor effect against polyphenol oxidase. Similar results for a* were reported in slices of mango coated with chitosan with a significant variation by Chien *et al.* (2007). The obtained results agreed with those reported in this study. It is possible to say that coatings with EOLs (CN and CL) prevent browning on mango samples during storage.

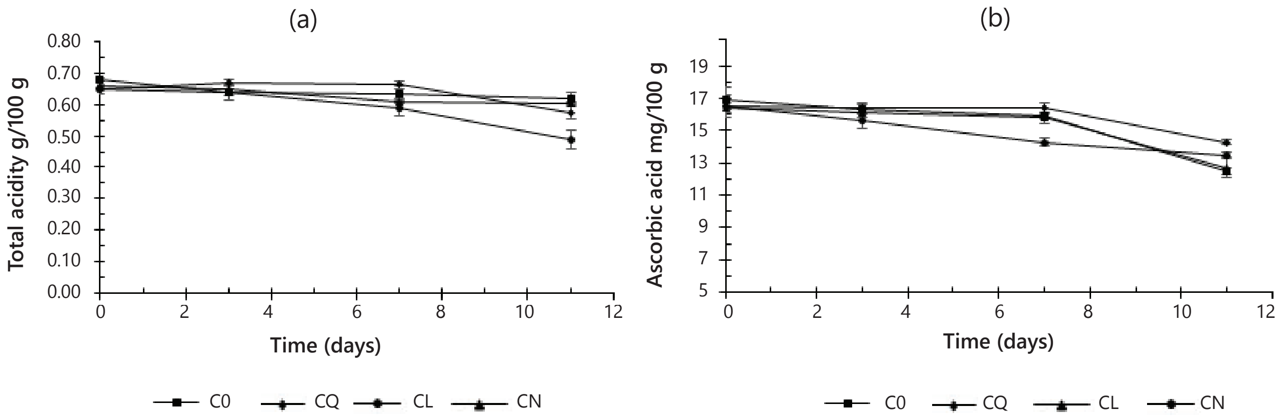

Figure 2. Total acidity (a) and ascorbic acid (b) contents in minimally processed mango. (MPM without coating (C0), with chitosan coating (CQ), with chitosan and orange (CN) and lemon (CL) essential oils).

Firmness and elasticity. Although firmness (Figure 3a) of the treatments on day 0 happened to be different, these variations were small due to error caused by the handling and contact point in the cubes during manipulations. However, this mechanical property had slight variations during the subsequent storage time. Uniformity in the measurements was also reported in this experiment. Statistical differences (p>0.05) were not found between the treatments. The MPM with CL

Table 2. Color Parameters in MPM with coating of chitosan and essential oils during refrigerated storage.

Sample		Day 0	Day 3	Day 7	Day 11
	a	-6.01 ± 0.57 a	-5.83 ± 0.35 a	-4.84 ± 1.34 a	-3.61 ± 1.16 a
C0	b	56.69 ± 2.56 a	54.61 ± 0.55 a	54.53 ± 6.29 a	63.00 ± 2.71 a
	L*	77.30 ± 2.53 a	76.59 ± 0.93 a	75.78 ± 2.26 a	80.05 ± 0.83 a
CQ	a	-4.50 ± 1.16 a,b	-3.60 ± 0.34 a,b	-4.72 ± 1.59 a, b	-6.20 ± 0.48 a, b
	b	58.56 ± 3.75 a	59.56 ± 5.55 a	52.22 ± 2.58 a	52.05 ± 3.74 a
	L*	75.47 ± 3.02 a	75.76 ± 0.70 a	75.35 ± 6.59 a	79.14 ± 2.35 a
	a	-3.57 ± 1.29 b	-5.05 ± 0.76 b	-6.42 ± 0.33 b	-6.31 ± 1.22 b
CN	b	59.57 ± 1.55 a	58.29 ± 1.26 a	55.42 ± 2.04 a	56.74 ± 4.80 a
	L*	73.75 ± 4.41a	77.77 ± 0.85 a	79.85 ± 1.54 a	77.33 ± 3.63 a
	a	-6.18 ± 1.04 b	-6.69 ± 0.17 b	-6.34 ± 0.29 b	-5.44 ± 0.96 b
CL	b	55.49 ± 2.81 a	54.03 ± 1.74 a	53.87 ± 2.97 a	58.51 ± 0.88 a
	L*	78.68 ± 1.31 a	77.17 ± 1.75 a	79.46 ± 0.99 a	76.08 ± 4.67 a

MPM without coating (C0), with chitosan coating (CQ), with chitosan and orange (CN) and lemon (CL) essential oils.
Values with the same letter within a column are not significantly different (P > 0,05).

showed a continuous reduction in firmness that was not significant. Beaulieu and Lea (2003) stated that the main quality problem after 7 days of storage in cut mango is related to firmness loss. In this study, the CH coatings seemed to delay firmness loss in the mango samples during storage. In the same sense, MPM presented a decrease in elasticity (Figure 3b), which, according to Palafox *et al.* (2012), was due to tissue degradation during the mango ripening process. The MPM did not present significant differences between the treatments ($p>0.05$) for elasticity. Elasticity decreases are mostly associated with moisture loss and tissue breakdown (Muda *et al.*, 1995).

Total phenols and antioxidant capacity. The total phenol content (Figure 4a) for the MPM samples with coatings showed a remarkable decrease in the first 3 days of storage. Starting with the third day, the values were almost constant until day 11. Statistically significant differences ($p>0.05$) were not found between the treatments. Melo *et al.* (2008), Ma *et al.* (2011) and Robles *et al.* (2009), in their studies with mango

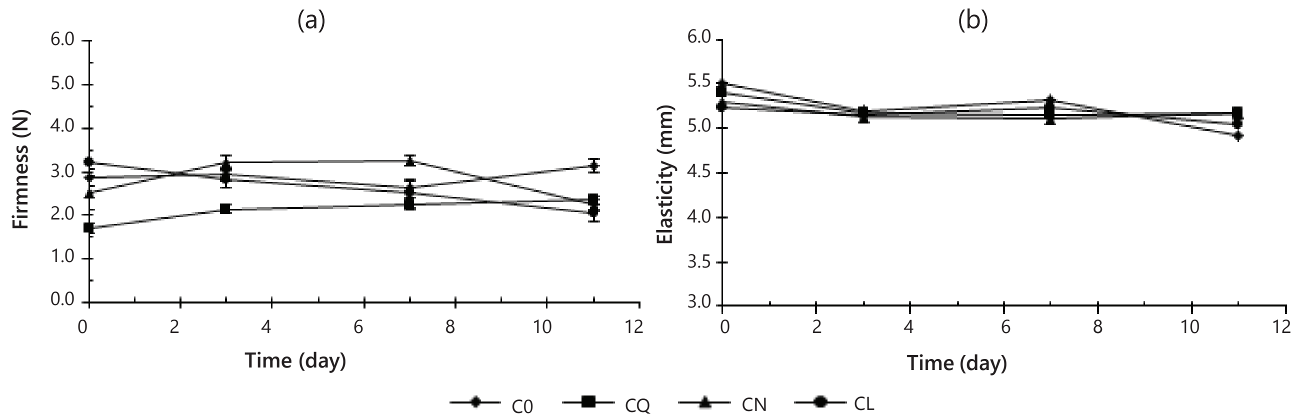

Figure 3. Firmness (a) and elasticity (b) in minimally processed mango. (MPM without coating (C0), with chitosan coating (CQ), with chitosan and orange (CN) and lemon (CL) essential oils).

cultivars, reported total phenols values (0.100 and 0.193 mg EAG/mL) below the control (0.197 mg EAG/mL for sample C0). The higher total phenol content in the samples of this study was in response to the lemon and orange EOLs composition: mainly phenolic compounds (Di Vaio *et al.*, 2010). The values obtained on day 11 of storage were the lowest for all of the treatments due to the oxygen presence and water solubility of flavonoids (Martínez-Flórez *et al.*, 2002; Melo *et al.*, 2008). This phenol compound reduction indicated migration of these compounds from the fruit and coatings to residual water. The antioxidant capacity, as measured

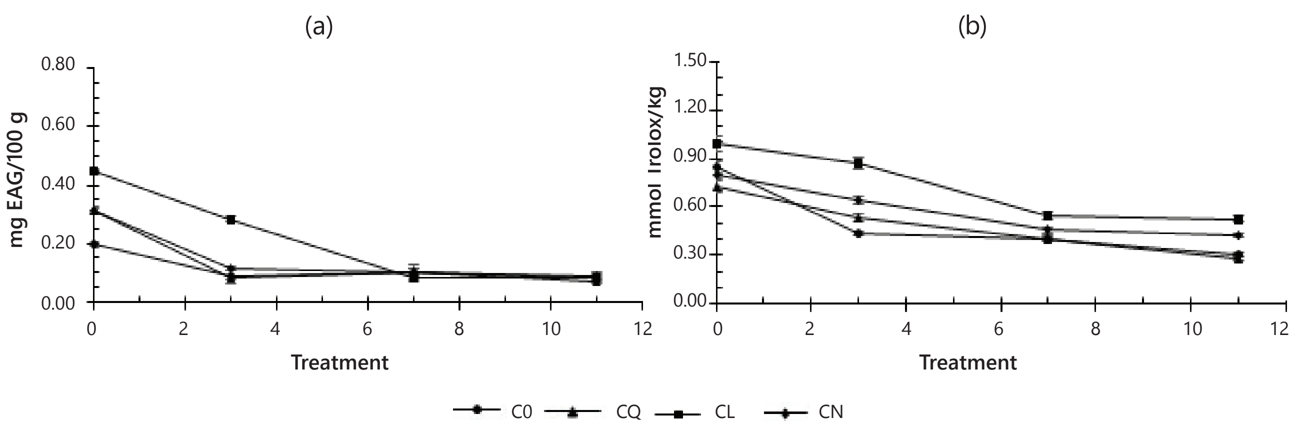

Figure 4. Total phenol (a) and antioxidant capacity (b) of minimally processed mango. (MPM without coating (C0), with chitosan coating (CQ), with chitosan and orange (CN) and lemon (CL) essential oils).

by FRAP (Figure 4b), decreased during storage. The CL exhibited the highest reduction from 0.991 mmol Trolox/kg to 0.525 mmol Trolox / kg on day 11. For all of the treatments, the antioxidant capacity was up to 0.7 mmol trolox/kg of the sample, even in the C0. This evidenced high amounts of antioxidant substances in the cultivar used in this study. The CN sample was significantly different ($p<0.05$) from the other samples during storage. According to the results, the CH coatings were not effective for preserving the EOL antioxidant activities after 3 days of storage. Values reported by Ma *et al*. (2011) were higher (>0.1 mmol Trolox/kg) than those presented in this study; nonetheless, these values were in the range obtained by Liu *et al*. (Liu *et al*., 2013) and Palafox *et al*. (2012). In Figure 4b, it is possible to observe that there was no effect from CH or EOL, as compared with the control (C0) or data reported in other studies (Liu *et al*., 2013; Ma *et al*., 2011; Palafox-Carlos *et al*., 2012); however, due to the orange and lemon EOL composition, the total phenol content was considerably affected.

Microbiological analysis. All of the evaluated treatments showed a decrease of total coliforms (Table 3) and no presence of fecal coliforms. After 11 days of storage, only the control (C0) presented a growing total coliform. The CQ, CN and CL presented inhibition after day 7. As reported by Dutta *et al.* (2009), CH has a bacteriostatic effect on Gram(-) bacteria. This activity and presence of EOLs in CN and CL could avoid coliform growth. A bacteriostatic effect against mesophilic bacteria was observed over time in the samples with coatings. Chien *et al.* (2007) reported 1.59 log CFU/g for mesophilic bacteria from day 0 to day 7 in mango coated with CH 1%. This study reported 1.48 log CFU/g for CQ and 0.68 log CFU/g for CL during the 11 days of storage. The interaction of CH and lemon EOL showed an additive effect against mesophilic bacteria. Growth was not reported for psychrophilic bacteria. The Mold and yeast content increased over time. However, values in the CQ, CN and CL were smaller than those reported for the control (C0). The CL showed a difference of 1.5 log CFU/g when compared to the control (C0) at the end of the assay. Previous assays reported for the chitosan antimicrobial effect against molds and yeasts in vegetable products (Ziani *et al*., 2009). Significant differences ($p>0.05$) between the MPM treatments were not found during storage for any of the evaluated microorganisms.

Table 3. Microbiological changes in minimally processed mango with coatings of chitosan and essential oils.

Time		(log CFU/mL) Day 0	Day 3	Day 7	Day 11
C0	*Total coliforms*	1.18 a	0.95 a	0.60 a	0.60 a
	Mesophilic	2.34 a	2.95 a	3.81 a	4.04 a
	Molds and yeasts	1.36 a	3.19 a	4.41 a	4.57 a
CQ	*Total coliforms*	1.18 a	0.48 a	0.00 a	0.00 a
	Mesophilic	2.36 a	2.93 a	3.48 a	3.85 a
	Molds and yeasts	0.00 a	1.00 a	3.87 a	4.00 a
CN	*Total coliforms*	0.95 a	0.85 a	0.00 a	0.00 a
	Mesophilic	2.40 a	2.74 a	3.40 a	3.57 a
	Molds and yeasts	0.00 a	1.00 a	3.18 a	3.31 a
CL	*Total coliforms*	1.08 a	0.85 a	0.00 a	0.00 a
	Mesophilic	2.36 a	2.70 a	2.99 a	3.04 a
	Molds and yeasts	0.54 a	1.54 a	2.78 a	3.02 a

Sensory evaluation. The MPM with CH and EOL coatings did not show significant differences ($p>0.05$) in general acceptance (color and visual appearance). This is because, as shown in the color evaluation and firmness tests, the CH coatings did not alter the color parameters for the MPM. On the contrary, parameters, such as luminosity, were unaltered. The CQ reported an off-flavor related to fish. This perception was due to the origin and concentration of the CH in the samples. The CN presented an off-flavor related to spoiled fruit. Therefore, the coatings of CH and orange EOL were not suitable for use with MPM as both samples were rejected by the panelists. However, the sensory analysis revealed that the C0 and CL had better scores for flavor and taste (Figure 5). These results were attributed to the mango consumption habit in Colombia. Mangoes are commonly consumed with lemon juice as seasoning.

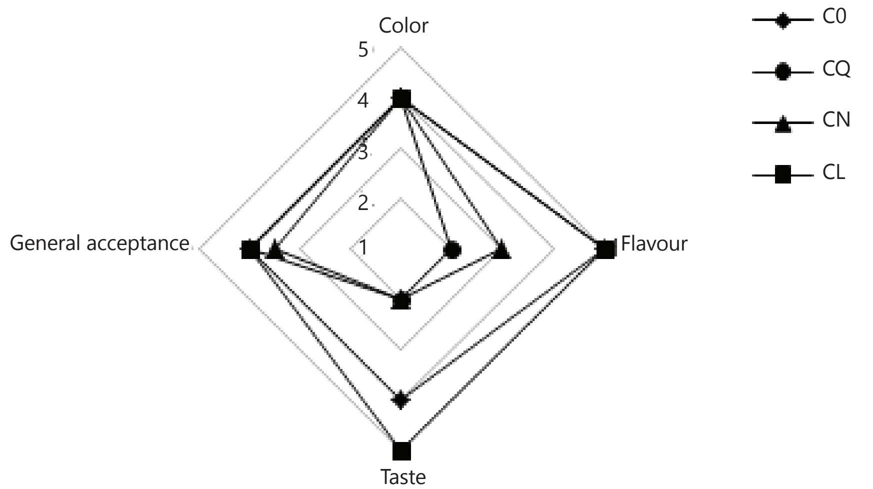

Figure 5. Sensory evaluation in samples of minimally processed mango (without coating (C0), with chitosan coating (CQ), with chitosan and orange (CN) and lemon (CL) essential oils).

CONCLUSIONS

The MPM with coating of CH and lemon EOL (CL) had the best acceptance by the panelists. Also, the total phenol content in this sample was among the highest. The stability of color, antimicrobial effect and firmness in the CL treatment showed that this coating is a viable option for MPM preservation. At any time during this study, the microbial growth values in the MPM affected the microbiological quality. The studied CH and EOL coatings did not have a significant effect on the firmness or elasticity of the MPM tissues during 11 days of storage. The total phenols and antioxidant capacity of the MPM were highly related to the studied coatings due to the EOL composition. The antimicrobial effect of the CN was lower than the one presented by the CL. Even though the physicochemical characteristics of the MPM with CH and orange EOL (CN) were acceptable, the sensory acceptance was lower than that of the MPM with CL and C0 due to off-flavors. CH and lemon EOL coatings can be considered for commercial purposes due to the characteristics conferred to MPM during refrigerated storage.

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