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.) minimamente procesado

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**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.

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
additional, 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 (Fernández-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 Tommy 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 sanitiy 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 %w/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 (Riley and Kajda, 1994). 1 g of pulp of each treatment was homogenized in an axolic 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 FeCl₃·6H₂O 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 (Holguín 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® – New Jersey, USA), tryptophan broth (Oxoid® – Ontario, Canada) and EMB agar (Merck® – New 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](image.png)

**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/ 100 g 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.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Day 0</th>
<th>Day 3</th>
<th>Day 7</th>
<th>Day 11</th>
</tr>
</thead>
<tbody>
<tr>
<td>C0</td>
<td>7.87 ± 0.42a</td>
<td>7.73 ± 0.64a</td>
<td>7.67 ± 0.58a</td>
<td>7.67 ± 0.61a</td>
</tr>
<tr>
<td>CQ</td>
<td>8.33 ± 0.64b</td>
<td>8.47 ± 0.58b</td>
<td>8.40 ± 0.72b</td>
<td>8.40 ± 0.80b</td>
</tr>
<tr>
<td>CN</td>
<td>7.67 ± 0.31a</td>
<td>7.80 ± 0.20a</td>
<td>7.87 ± 0.46a</td>
<td>8.07 ± 0.31a</td>
</tr>
<tr>
<td>CL</td>
<td>7.67 ± 0.31a</td>
<td>7.73 ± 0.23a</td>
<td>7.73 ± 0.23a</td>
<td>7.93 ± 0.12a</td>
</tr>
</tbody>
</table>

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.
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(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.

**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.

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

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 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 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).](image)

![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).](image)
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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.

**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

<table>
<thead>
<tr>
<th>Time</th>
<th>Total coliforms</th>
<th>Mesophilic</th>
<th>Molds and yeasts</th>
<th>Total coliforms</th>
<th>Mesophilic</th>
<th>Molds and yeasts</th>
<th>Total coliforms</th>
<th>Mesophilic</th>
<th>Molds and yeasts</th>
</tr>
</thead>
<tbody>
<tr>
<td>C0</td>
<td>1.18 a</td>
<td>2.34 a</td>
<td>1.36 a</td>
<td>1.18 a</td>
<td>2.36 a</td>
<td>0.00 a</td>
<td>0.95 a</td>
<td>2.34 a</td>
<td>1.36 a</td>
</tr>
<tr>
<td>CQ</td>
<td>2.34 a</td>
<td>3.64 a</td>
<td>4.31 a</td>
<td>2.36 a</td>
<td>3.40 a</td>
<td>0.00 a</td>
<td>2.95 a</td>
<td>3.95 a</td>
<td>4.31 a</td>
</tr>
<tr>
<td>CN</td>
<td>1.36 a</td>
<td>3.19 a</td>
<td>4.41 a</td>
<td>0.00 a</td>
<td>1.00 a</td>
<td>3.87 a</td>
<td>0.85 a</td>
<td>2.95 a</td>
<td>4.41 a</td>
</tr>
<tr>
<td>CL</td>
<td>0.54 a</td>
<td>1.54 a</td>
<td>2.78 a</td>
<td>0.85 a</td>
<td>2.70 a</td>
<td>3.02 a</td>
<td>0.00 a</td>
<td>2.95 a</td>
<td>4.31 a</td>
</tr>
</tbody>
</table>

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

**REFERENCES**


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