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Edible coatings with avocado oil on the quality of 'Tommy Atkins' mangoes

Coberturas comestíveis com óleo de abacate na qualidade de mangas 'Tommy Atkins'

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ABSTRACT

One of the main, most effective and economical techniques used in the preservation of fresh fruits is the edible coatings. We applied 0.53% and 2.52% avocado oil coatings to 'Tommy Atkins' mangoes at ripening stage 2. The treatment control comprised uncoated mangoes. The fruits were stored at 15 °C ±2°C and 80% ±5% relative humidity (RH) and at ambient conditions of 26 °C ±2°C and 75% ±5% RH for 24 days. Several physicochemical parameters (pH, soluble solids, titratable acidity, firmness, and weight loss), color-related characteristics, and microbiological and sensory characteristics were periodically analyzed. The results indicated that the combined effect of 2.52% avocado oil coating and refrigerated storage at 15 °C ±2°C and 80% ±5% RH led to a decrease in water loss (by 20%) at the end of the storage period, delayed mango senescence, inhibited microbial growth (indicated by the absence of molds and *Escherichia coli*), and did not influence sensory attributes of the fruit. Thus, avocado oil coating might be used to preserve the fruit for up to 24 days.

Index Terms: *Mangifera indica*; physicochemical attributes; microbial counts; shelf life.

RESUMO

Uma das principais, mais eficazes e econômicas técnicas utilizadas na preservação de frutas frescas são os revestimentos comestíveis. Revestimentos contendo óleo de abacate a 0,53 e 2,52% foram aplicadas em mangas da variedade 'Tommy Atkins' no estádio de maturação 2. O tratamento controle consistiu de mangas sem cobertura. Os frutos foram armazenados a 15 ±2 °C e 80 ±5% UR, e em condições ambientais de 26 ±2 °C e 75 ±5% UR por 24 dias. Análises físico-químicas (pH, sólidos solúveis, acidez titulável, firmeza, perda de peso), cor, análises microbiológicas e sensoriais foram realizadas periodicamente. Os resultados mostraram que o efeito combinado do armazenamento refrigerado a 15 ±2 °C, 80 ±5% UR e 2,52% de revestimento de óleo de abacate, diminuiu a perda de agua com 20% no final da armazenamento, atrasou a senescência da manga, inibiu o crescimento microbiano com ausência de bolores e E. coli, não influenciou nos atributos sensoriais e é uma alternativa viável para conservar a fruta por até 24 dias.

Termos para Indexação: *Mangifera indica*; atributos físico-químicos; contagens microbianas; vida de prateleira.

INTRODUCTION

An increase in the demand for higher-quality products in domestic and foreign markets has pushed fruit exporters to improve their technological capacities. Mangoes have a high demand in the market because of their sensory attributes and high nutritional value (Wei; Mei; Xie, 2021). The 'Tommy Atkins' mango variety is valuable for export because of its high resistance to mechanical damage and long shelf life (De Oliveira et al., 2020).

To preserve mangoes for longer, various strategies, such as the use of edible coatings, have been proposed. These coatings act as barriers and preserve the fruits via the balanced permeability of CO_2, O_2, and water vapor, thus reducing the weight loss of the fruit, delaying senescence, and reducing the growth of pathogenic microorganisms, which can lead to postharvest deterioration (Tavassoli-Kafrani et al., 2022). Edible coatings can also delay senescence and prevent chilling injury (Kehila et al., 2021). For preserving mangoes, the primary coating materials include chitosan, waxes (especially carnauba wax), starches, gums (especially gum arabic), and cellulose derivatives (Tavassoli-Kafran et al., 2022).

Coatings formulated using different concentrations of virgin avocado oil (1.20% and 2.08%), along with refrigeration, can be applied to prevent the growth of microorganisms and maintain the sensory attributes of fresh-cut 'Tommy Atkins' mangoes (Dussán-Sarria; Ramírez-Yela; Hleap-Zapata, 2017). However, no study has reported the effects of these edible coatings on fresh whole fruits. Therefore, in this study, we hypothesize that the application of an edible avocado oil coating to whole mangoes affects their quality attributes. We evaluated the effects of two avocado oil-based edible coating formulations on the quality of fresh 'Tommy Atkins' mangoes stored under refrigeration and room temperature conditions.

MATERIAL AND METHODS

Location and raw materials

Mangoes of the 'Tommy Atkins' cultivar were purchased from the local market of Palmira City, Colombia. The mangoes exhibited maturity grade 0 on a scale of 0–4 (25% maturity) according to the NTC 5210 standard (Instituto Colombiano de Normas Técnicas y Certificación -ICONTEC, 2003). The fruits were selected and graded based on their weight (average weight of each fruit: 400 g). We evaluated the mangoes over 32 days in the fruit and vegetable laboratory of UNAL - Palmira. Avocado oil sold under the brand name OLEO HASS had the following characteristics: avocado 'Hass' variety, translucent liquid, yellow to golden in color with green tones, with characteristic odors and fruit flavors, free acidity (% oleic acid) of 0.38% ±0.01%–0.70% ±0.11%, and moisture content (% h.b.) of 0.13–0.38.

Application of the edible coating

The fruits were initially washed with neutral detergents and potable water. The fruits were then sanitized by immersing them in a sodium hypochlorite solution at 10 ppm for 1 min, drained for 2 min, and treated with a solution of citric acid (1% w/w), ascorbic acid (1% w/w), and calcium chloride (1% w/w) for 5 min (Dussán-Sarria; Torres-León; Reyes-Calvache, 2014). For the coating formulations, the methods reported by Dussán-Sarria, Torres-León, and Hleap-Zapata (2014) were followed. The quantity of ingredients used was different; specifically, the percentage of avocado oil was different, which acted as a barrier to water vapor in the emulsion. Xanthan gum was added as a stabilizer to homogenize the emulsion, and stearic acid was added to reduce the melting point of the carnauba wax. The percentage of the formulations used (Table 1) was previously determined with affective sensory analyses of fruit appearance. The fruits were separated into two batches. Then, they were immersed in solutions F1 and F2 for 2 min and subsequently removed. The coated fruits were kept under a fan (26 °C) for 3 min for the coating to adhere firmly to the surface. In total, 78 fruits were treated at 15 °C, and 62 fruits were treated at 26 °C.

Table 1: Formulation components of the edible coatings (F1 and F2).

Components	F1 (%)	F2 (%)
Carnauba wax	0.33	1.58
Glycerol	2.23	2.54
Avocado oil	0.53	2.52
Stearic acid	0.53	2.56
Cassava starch	2.03	2.3
Xanthan gum	0.11	0.12
Water	94.25	88.38
Total	100	100

Storage

The fruits were stored in rigid plastic baskets (40 × 30 × 20 cm). They were stored under two different conditions: at 15 °C ± 2 °C and 80% ± 5% relative humidity (RH) and at 26 °C ± 2 °C and 75% ± 5% RH for up to 32 days. The quality attributes were evaluated every four days until the end of the storage period. The storage conditions of 26 °C ± 2 °C and 75% ±5% simulated room temperature conditions.

Physicochemical attributes

To determine the physicochemical and sensory attributes, we destructively analyzed three mangoes per treatment every four days of storage. The pH was determined using a Metrohm pH meter with a 744 potentiometer according to the Colombian standard NTC 4592 (ICONTEC, 1999). Soluble solids were evaluated using a Pocket Atago PAL-1 digital refractometer. All attributes were measured directly in °Brix according to NTC 4624 (ICONTEC, 1999). The percentage of titratable acidity was evaluated by titrating the mango juice with a 0.1 N NaOH solution using a SCHOTT CG842 pH meter. The acidity was expressed as the percentage of citric acid based on NTC 4623 (ICONTEC, 1999). The firmness of the fruit flesh was measured using a penetrometer with an 8-mm diameter probe that was perpendicular to the surface of the peeled sample. The values were expressed as kgf. Percentage cumulative weight loss during storage was determined using Equation 1 (Shehata et al., 2020) with a Mettler Toledo precision balance.

$$\mathrm{WL}(\%) = \frac{W_i - W_f}{W_i} \times 100 \quad (1)$$

Here, WL indicates the percentage of weight loss, W_i indicates the initial fruit weight (g), and W_f indicates the final weight (g).

Color evaluation

The colors of the mango pulp were determined using a Konica Minolta colorimeter model Chroma Meter Cr 400 in CIE Lab coordinates. The equipment was calibrated using a D65 illuminant and a 10° observer. The results were presented in terms of L* (L*= 0 for black and L*= 100 for white, a* (green (−) and red (+), and b* (blue (−) and yellow (+)). From these coordinates, the parameters C* (chroma) and H* (hue) were calculated using Equations 2 and 3, respectively (Dussán-Sarria; Ramírez-Yela; Hleap-Zapata, 2017).

$$C^* = \sqrt{a^{*2} + b^{*2}} \quad (2)$$

$$H^* = \tan^{-1}\left(\frac{b^*}{a^*}\right) \quad (3)$$

Microbiological analyses

The mango samples were obtained from each treatment at the beginning and end of the storage period and analyzed at Synlab's Bioindustrial Laboratory located in Cali, Colombia. We quantified the total number of mesophiles (CFU/g) according to the (Association of Officiating Analytical Chemists - AOAC 966.23 (2019), mold count according to the (International Organization for Standardization - ISO 21527–2 2008), and *Escherichia coli* count according to the NTC 4458 (ICONTEC, 2007).

Sensory analyses

We considered 30 untrained consumers as judges aged between 20 and 50 years from any ethnicity. Sensory analyses were conducted at 0, 15, and 30 days of storage. The degree of acceptance was evaluated based on the appearance, aroma, texture, color, and flavor of the whole fresh mango using the sensory affective assay. An unstructured linear 10-cm scale was used with qualitative expressions, where (1) represented "I did not like it at all", and (10) represented "I liked it extremely". A score of 5 was the minimum acceptable score in this study (Dussán; Ramírez-Yela; Hleap-Zapata, 2017).

Experimental and statistical analyses

We used a completely randomized design. We analyzed six treatments based on the two formulations (F1 and F2) and two storage conditions (Table 2). To determine the physicochemical and sensory attributes, destructive analyses were conducted with a sample of three mangoes per treatment every four days of storage. Each destructive sample was considered an experimental unit in all analyses. The data were analyzed using the statistical program Statistical Analysis System (SAS) version 9.3. Descriptive statistical data analyses, analysis of variance over time, and comparison of means were conducted using Tukey's test. All results were considered to be statistically significant at $p < 0.05$.

Table 2: Designation of evaluated treatments.

Designation	Treatments
Control; 15 °C	Uncoated. Storage at 15 °C ± 2 °C and 80% ± 5% RH
F1; 15 °C	Formulation 1. Storage at 15 °C ± 2 °C and 80% ± 5% RH
F2; 15 °C	Formulation 2. Storage at 15 °C ± 2 °C and 80% ± 5% RH
Control; 26 °C	Uncoated. Storage at ± 26°C and 75% ± 5% RH
F1; 26 °C	Formulation 1. Storage at 26 °C ± 2 °C and 75% ± 5% RH
F2; 26 °C	Formulation 2. Storage at 26 °C ± 2 °C and 75% ± 5% RH

RESULTS AND DISCUSSION

Physicochemical attributes

The results of the analysis of variance showed that the application of the edible coating on whole mangoes, storage time, and a combination of these factors significantly affected the physicochemical properties of the mangoes (pH, soluble solids, titratable acidity, firmness, and weight loss) ($p < 0.05$). The difference in the pH of the coated and uncoated (control) mangoes was statistically significant ($p < 0.05$) (Figure 1). The pulp of the fruits coated with edible coating during storage had a lower pH. This occurred because of the effect of the coating, which slowed down the ripening process, leading to an accumulation of organic acids. Similar properties were reported by Dussan-Sarria, Torres-León and Reyes-Calvache (2014) and Qambrani et al. (2022). During the last days of storage, the pH stabilized because of the conversion of organic acids into sugars, increased enzymatic activities, and the onset of fruit senescence (El-Baz; Toliba; El-Shorbagy, 2021). At the end of the storage period, the fruits treated with the edible coating had an average pH of 3.5, whereas the average pH of uncoated fruits was 4.5.

The levels of soluble solids (SS) exhibited some peaks during the middle of storage, which progressively increased and decreased in the coated samples and control samples, respectively (Figure 2). This increase in SS levels corresponds to the characteristic peak of climacteric fruits such as mango (Ebrahimi; Rastegar, 2020).

The levels of SS in the coated mango decreased because the coatings decreased the rate of respiration, leading to the slow ripening of the fruit (Wei; Mei; Xie, 2021). The levels of SS increased, despite the action of the coatings, because temperature favored the enzymatic reactions, inducing the hydrolysis of starch to sugars (De los Santos-Santos et al., 2020).

The values of titratable acidity (TA) of the fruits decreased during storage without any significant differences between coated and uncoated fruits ($p < 0.05$) (Figure 3).

During storage under different treatment conditions, the variation in TA values was low, starting at approximately 0.8% and ending at 0.3%. The low variation in TA values was not in contrast to the significantly decreased pH values of the fruit during storage because the temperature and modified atmosphere resulted in the differences in the permeability of the coating. This was true, especially for the O_2 content, which decreased the metabolic process, delaying the enzymatic degradation of citric acid (Santacruz-Terán, 2021).

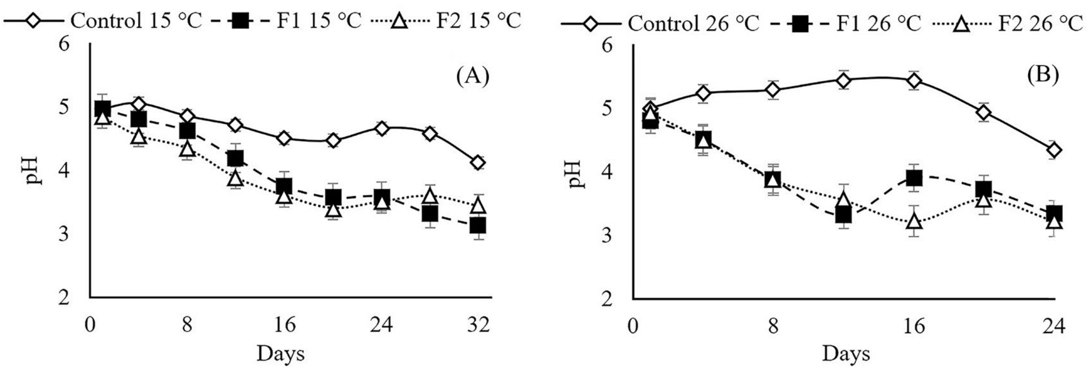

Figure 1: The pH of mangoes with or without an edible avocado oil coating (two formulations: F1 and F2) stored at 15 °C (A) and 26 °C (B); Standard error (ɪ) 2.5.

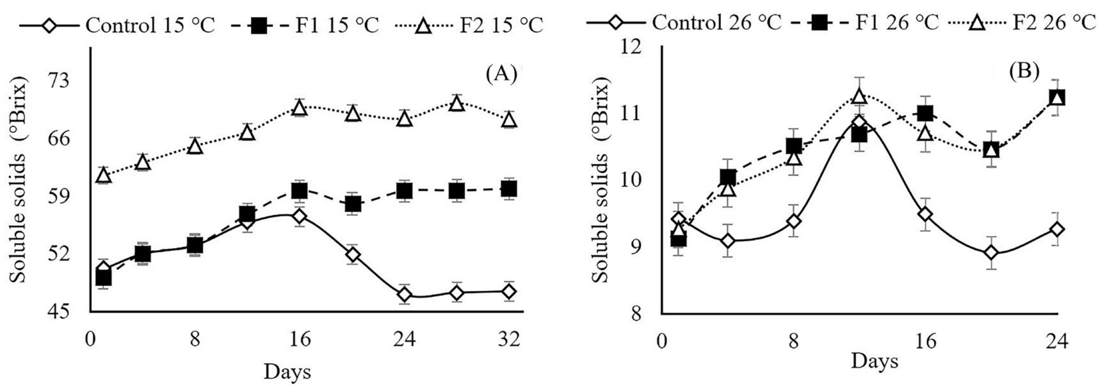

Figure 2: The levels of soluble solids of mangoes with or without an edible avocado oil coating (two formulations: F1 and F2) stored at 15 °C (A) and 26 °C (B); Standard error (ɪ).

Firmness is an important quality of mango because it strongly influences the consumer when selecting and purchasing fresh fruit (Ates et al., 2022). The firmness of mango flesh decreased throughout storage (Figure 4). Fruit softening is caused by the degradation of pectic substances, hemicellulose, and cell wall cellulose. It is also caused by the loss of cell turgidity during ripening and the onset of senescence (Ates et al., 2022).

At 15 °C (Figure 4A), the firmness of the fruits was maintained for a longer time during storage, up to day 24, whereas the firmness of the fruits stored at 26 °C with a similar value of 1.5 kgf was maintained up to day 16. Similar values were reported by Shah et al. (2021) for the firmness of mango pulp during the same duration of storage. They reported that the edible coating formulated with chitosan and thyme oil composites maintained the firmness of the whole mango during storage. The fruit was preserved for a longer duration due to the lower storage temperature.

The weight loss in uncoated control fruits at 26 °C and 15 °C was significantly higher than that in coated fruits throughout storage ($p < 0.05$) (Figure 5). The fruits that were treated with edible coatings exhibited an average weight loss of 20% at the end of the storage period, whereas, uncoated fruits exhibited an average cumulative weight loss of 33%. The edible coatings led to a decrease in the respiration rate, and consequently, a lower weight loss. This phenomenon was attributed to the barrier effect associated with the lipid phase of the coatings, whose hydrophobic nature decreased the permeability of water vapor through the mango surface (Kawhena; Opara; Fawole, 2022). These results showed that both F1 and F2 formulations delayed the respiration and transpiration of mangoes. The mangoes coated with F2 and stored at 15 °C presented the least weight loss during the whole storage period. Qambrani et al. (2022) showed that edible coatings with castor oil significantly decreased water loss when applied to the surfaces of whole mangoes.

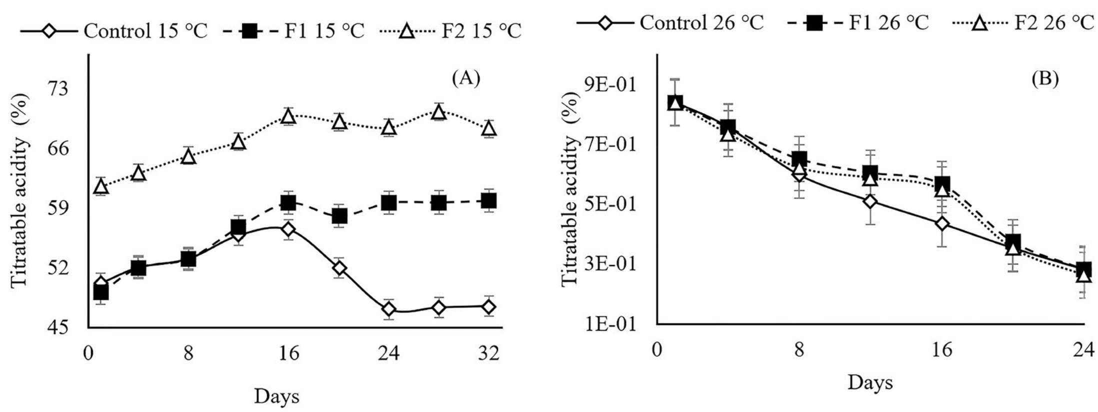

Figure 3: The titratable acidity values of mangoes with or without an edible avocado oil coating (two formulations: F1 and F2) stored at 15 °C (A) and 26 °C (B); Standard error (ı).

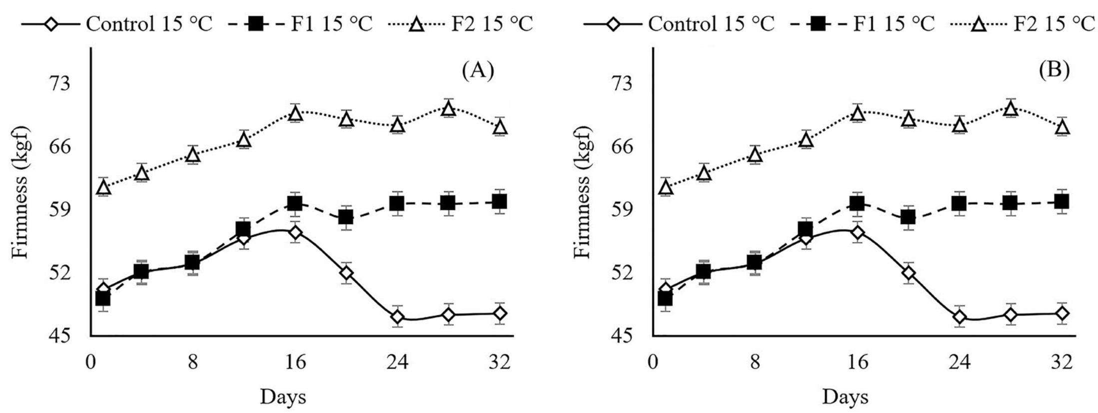

Figure 4: The firmness of mangoes with or without an edible avocado oil coating (two formulations: F1 and F2) stored at 15°C (A) and 26°C (B); Standard error (ı).

Color parameters

The mangoes that were treated with the F2 formulation exhibited the highest values of the color coordinates L* at both 15 °C and 26 °C ($p < 0.05$) (Figure 6). Increased L* values are directly related to the development of fruit ripening and the conversion of chlorophylls to carotenoids (Barion et al., 2020). However, in this study, the F2 formulation had higher contents of avocado oil and carnauba wax, which may have contributed to the higher surface brightness of the fruits. Chitosan coating enriched with cinnamon oil slowed down the weight loss and maintained the color of the whole mango compared to the control (Dong; Thuy, 2021).

Uncoated control mangoes exhibited the lowest L* values. Mangoes treated with F2 formulation and stored at 15 °C and those treated with F2 formulation and stored at 26 °C exhibited the highest values of the color parameter C*, followed by the control mangoes, possibly because they reflect greater reddish and yellowish tones with higher values of the a* and b* coordinates that determine the chroma (C*) value and highlight fruit ripening (Oliveira, et al., 2020). Mangoes treated with the F1 coating had lower C* values than those coated with F2 ($p < 0.05$) (Figure 7).

The higher contents of avocado oil and carnauba wax in the F2 formulation probably decreased gas exchange and metabolic activity because of the physical barrier and improved ripening of the fruit, resulting in higher values of chroma (C*) and gloss (L*) on the surface of the mangoes (Wei; Mei; Xie, 2021).

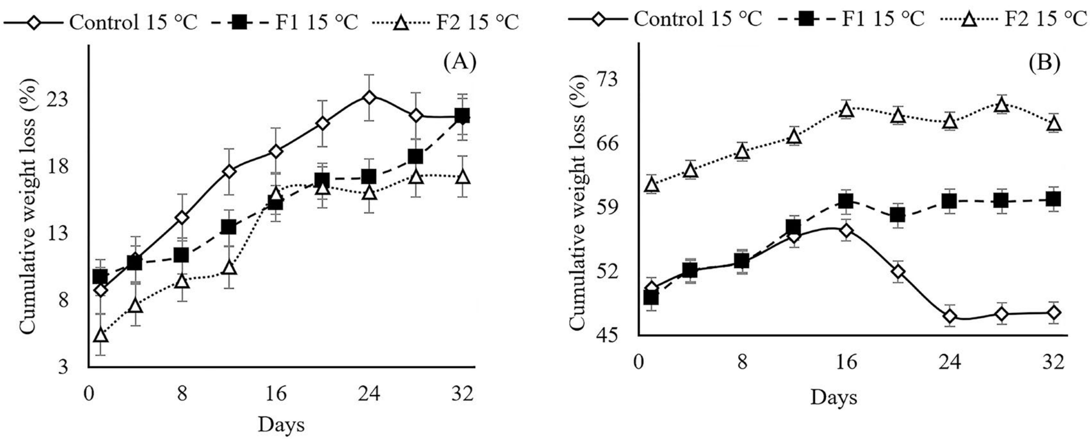

Figure 5: The percent weight loss of mangoes with or without an edible avocado oil coating (two formulations: F1 and F2) stored at 15 °C (A) and 26 °C (B); Standard error (ı).

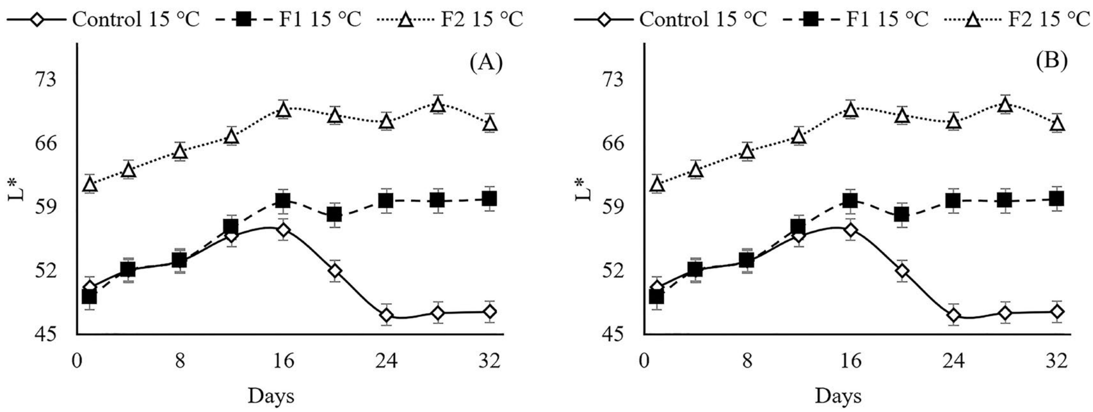

Figure 6: The L* coordinate values of mangoes with or without an edible avocado oil coating (two formulations: F1 and F2) stored at 15 °C (A) and 26 °C (B); Standard error (ı).

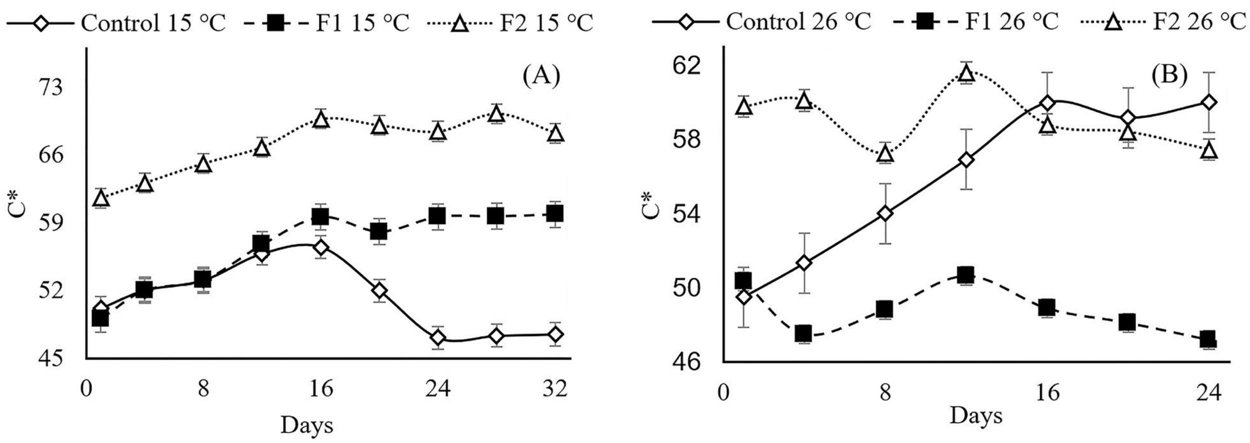

Figure 7: The C* (chroma) values of mangoes with or without an edible avocado oil coating (two formulations: F1 and F2) stored at 15 °C (A) and 26 °C (B); Standard error (ı).

Control fruits without edible coating showed signs of enzymatic browning at both 15 °C and 26 °C, as indicated by the results of the color evaluation (Miteluț et al., 2021). The hue values (H*) of the mangoes did not significantly differ between treatments and storage time. Fruits without edible coatings had more prominent red to yellow shades, according to the CIE Lab system.

In mangoes with guar-based edible coatings enriched with aloe vera extract that were stored at ambient temperatures, changes in the peel color during storage were much lower in the coated fruits than in control fruits (Ebrahimi; Rastegar, 2020). According to Chuacharoen and Sabliov (2022), the coating material formulated by using curcumin-loaded zein nanoparticles prolonged the postharvest quality of mangoes under storage conditions of 25 °C for nine days, as determined by delayed color change, weight loss, and firmness.

Microbiological analyses

At the beginning of storage, total coliforms and molds were present on the fruit surface, and *E. coli* and yeasts were absent on the fruit surfaces. Molds were present because of agricultural activities, whereas, total coliforms were present because of human interaction and the materials used during processing (Artés-Hernández et al., 2021). At the end of the storage period, control mangoes (without edible coating) exhibited a total coliform count of 89 CFU/g, an absence of molds, and an absence of *E. coli*. The edible coating with a combination of chitosan enriched with cinnamon oil not only reduced the negative effects on mango peel cells but also maintained the antifungal properties of whole mangoes during storage (Dong; Thuy, 2021). None of the mangoes used in this experiment exceeded this level throughout storage, according to NTC 6005 (ICONTEC, 2013).

Sensory analyses

The mangoes subjected to the six treatments exhibited a decrease in sensory scores during storage (Figure 8). Control mangoes exhibited lower scores for all sensory attributes, except for color, during storage.

Fruits treated with the F2 formulation and stored at 15 °C exhibited the most suitable sensory properties, followed by those treated with the F1 formulation and stored at 15 °C. The low storage temperature and F2 coating allowed the mangoes to be acceptable based on sensory qualities until day 24 of storage, with maturity grade 4 on a scale of 0–4 (100% maturity) according to NTC 5210 (ICONTEC, 2003). The mangoes in the control group stored at 15 °C had no consumption quality after 24 days of storage. Adequate doses of essential oils facilitated coating formulations that preserved the fruits without altering the sensory characteristics (Batista et al., 2020). Oliveira et al. (2020) reported that fresh mangoes coated with essential oils and chitosan and stored for 30 days at 15 °C had scores >7 on a scale of 1–10 in all sensory attributes.

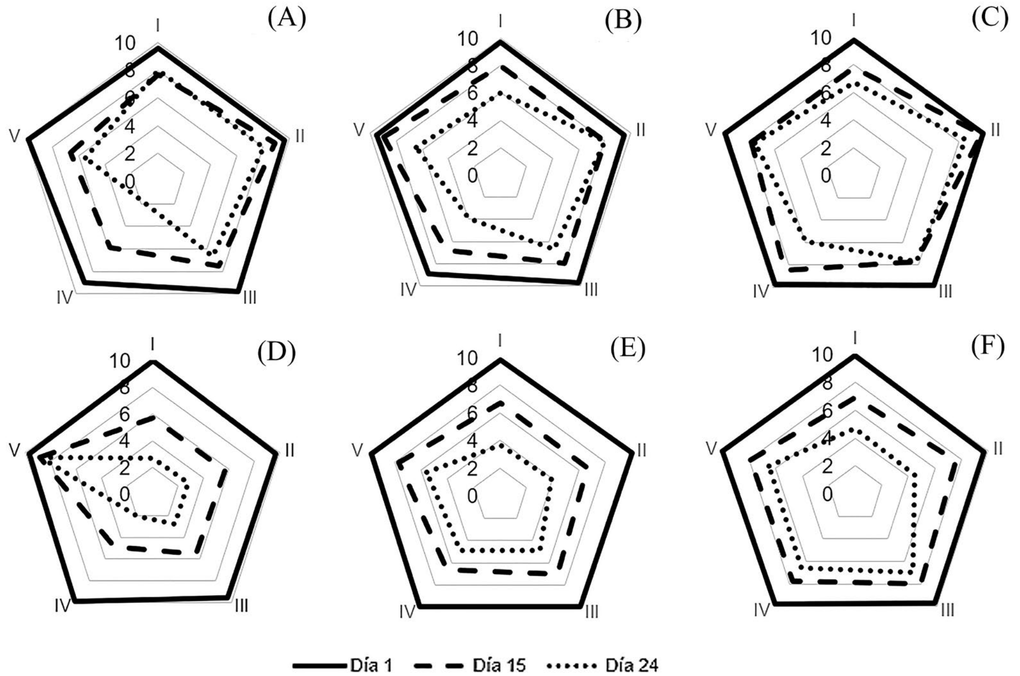

Figure 8: Sensory analysis of mangoes with or without an edible avocado oil coating (two formulations: F1 and F2). Control at 15 °C (A), F1 formulation at 15 °C (B), F2 formulation at 15 °C (C), control at 26 °C (D), F1 formulation at 26 °C (E), and F2 formulation at 26 °C (F), aroma (I), taste (II), texture (III), appearance (IV), and color (V).

CONCLUSIONS

Edible coatings composed of avocado oil, carnauba wax, cassava starch, and xanthan gum affect the quality attributes of 'Tommy Atkins' mangoes. The edible coating F2 with 2.52% avocado oil (w/w) was applied to the whole fruit and stored at 15 °C ± 2 °C and 80% ± 5% RH. This might be a viable alternative for preserving the fruit for up to 24 days, as it can slow down the ripening process, preserve the sensory attributes, and increase the shelf life.

AUTHOR CONTRIBUTION

Conceptual idea: Dussán-Sarria, S.; Methodology design: Dussán-Sarria, S.; Hleap-Zapata, J. I.; Data collection: Dussán-Sarria, S.; Hleap-Zapata, J. I.; Data analysis and interpretation: Dussán-Sarria, S.; Hleap-Zapata, J. I. and Writing and editing: Dussán-Sarria, S.; Alvis-Bermúdez, A.

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