



Starch-Based Coating from ‘Tommy Atkins’ Mango Seed Almond with Added Plasticizers for Post-Harvest Preservation of Mangoes

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ABSTRACT. This study investigates the potential of starch-based coatings derived from ‘Tommy Atkins’ mango seed kernels, integrated with glycerol and sorbitol as plasticizers, as a sustainable solution for the post-harvest preservation of mangoes (*Mangifera indica* L.). Utilizing agro-industrial by-products, the research offers an innovative and biodegradable alternative to synthetic coatings, addressing critical environmental and economic challenges. Six filmogenic solutions with varying starch concentrations (1%, 2%, and 3%) were applied to mangoes, which were stored at 13°C for 30 days. Evaluations were conducted every five days, analyzing mass loss, firmness, browning, soluble solids content, pH, and titratable acidity. The results showed that coatings with higher starch concentrations (2% and 3%) significantly reduced mass loss, preserved fruit firmness, and delayed skin browning compared to uncoated control samples. These coatings also maintained internal fruit quality, ensuring stable pH levels and controlled increases in soluble solids content. By extending the shelf life of mangoes and reducing post-harvest losses, the study highlights the efficacy of starch-based coatings in preserving fruit quality during storage. Beyond technical performance, this approach promotes circular economy practices by valorizing mango processing residues and reducing environmental impact. It offers an accessible, cost-effective solution for small-scale producers, particularly in regions with abundant mango cultivation and processing. The research emphasizes the role of starch-based coatings as a promising avenue in sustainable post-harvest technologies, with the potential to enhance economic opportunities and reduce waste in the agro-industrial sector.

Keywords: agro-industrial by-products; *Mangifera indica* L.; physico-chemical characteristics; plasticizers; shelf life extension.

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Introduction

Mango (*Mangifera indica* L.), also known as the ‘king of fruits’, is the second most economically substantial tropical fruit commodity worldwide (Vincent & Anushma, 2023; Ooi et al., 2016). It is largely consumed due to its unique characteristics, such as delicacy, favorable aroma, high nutritive value, and general eating features (Esguerra & Rolle, 2018).

Mango can be cultivated in tropical and subtropical regions and is grown commercially in more than 88 countries, led by India, China, Thailand, Indonesia, and Mexico, respectively (Vincent & Anushma, 2023). The global annual production of mango is nearly 52 million tons in 2018 (Altendorf, 2019) and the most famous cultivar is ‘Tommy Atkins’ due to its relative resistance to disease, good maturity, easy postharvest handling and proper shelf life (Nayak et al., 2023; Ooi et al., 2016).

More than 95% of the world’s mango trade is in the form of fresh fruit, but it faces significant limitations due to the rapid ripening and highly perishable nature of mangoes (Gelaye, 2024). These factors lead to substantial post-harvest losses, often ranging from 25 to 40%, and require costly storage solutions like refrigeration and controlled atmospheres (Vincent & Anushma, 2023). Small-scale farmers often lack access to these technologies, and long-distance transport further increases costs and risks of spoilage (Gelaye, 2024; Vincent & Anushma, 2023). Innovative post-harvest technologies are essential to reduce losses and improve profitability in the mango trade.

As a climacteric fruit, mangoes undergo an increase in respiration and ethylene production during ripening, which accelerates the process once harvested (Liu et al., 2022; Oliveira et al., 2020). At room temperature, mangoes ripen quickly, within 3 to 9 days, resulting in tissue softening and increased susceptibility to microbial attack (Hoque et al., 2018; Rastegar, Khankahdani, and Rahimzadeh, 2019).

Moreover, mangoes are prone to water loss, microbial spoilage, chilling injury, and mechanical damage, which complicates handling, storage, and long-distance trade (Esguerra and Rolle, 2018; Hoque et al., 2018). These vulnerabilities lead to significant losses, with 25 to 40% of fresh mangoes lost from harvest to consumer, primarily due to water loss and diseases such as anthracnose and stem-end rot (Evans et al., 2017; Nor & Ding, 2020).

To minimize these losses and maintain mango quality, various post-harvest operations have been implemented, including de-latex treatment, hot water treatment, pre-cooling, controlled and modified atmosphere storage, ionizing radiation, synthetic fungicides, chemical treatments, hypobaric storage, and edible coatings (Esguerra & Rolle, 2018; Hoque et al., 2018; Ooi et al., 2016; Rastegar et al., 2019). These techniques help extend the shelf life of fresh and cut mangoes, ensuring they reach the final consumer in good condition.

Most plastic packaging is derived from petroleum, a significant source of pollution. In the search for alternatives to extend the shelf life and maintain the post-harvest quality of fruits and vegetables, edible coatings emerge as a promising solution. These coatings act as a barrier to prevent degradation, water loss, and consequently, weight loss in fruits and vegetables (Valdés et al., 2017; Silva et al., 2022).

During the industrial processing of mangoes, a significant amount of waste is generated and discarded without proper treatment. Among these wastes is the mango seed kernel, which has a high starch content and important antioxidant properties (Torres-León et al., 2018; Bharti et al., 2019). The use of agro-industrial by-products, such as fruit seeds, offers alternatives for the development of clean and sustainable technologies. Coatings made with starch extracted from these residues not only add value to these materials but also help reduce environmental impacts and post-harvest losses (Silva et al., 2016). Additionally, this approach is innovative compared to other biopolymers because it leverages waste materials, reducing costs and reliance on primary resources, while promoting circular economy practices. This makes it a practical and eco-friendly alternative for small-scale producers, particularly in regions with abundant fruit processing residues.

Edible coatings are applied as a thin layer of gelatinized material, with or without the addition of a plasticizing agent, such as glycerol or sorbitol (Nawab et al., 2017). This semipermeable layer forms a modified atmosphere around the fruits, which helps maintain their appearance, attractiveness, and shine, in addition to reducing respiratory rates, water loss, and delaying ripening (Rodrigues et al., 2016).

Studying the maturation and development of fruits is essential to determine the ideal harvest time and post-harvest shelf life. In this context, many studies are focused on evaluating the fruits and the transformations that occur during the maturation process. Some studies investigate the effectiveness of different coatings in maintaining fruit quality and changes due to ripening. Thus, the use of edible coatings made from starch extracted from mango seed kernels presents itself as an excellent alternative for post-harvest conservation of fruits and vegetables.

To date, different biopolymers have been investigated to produce edible films and coatings. They can be classified into three main groups: polysaccharides (e.g. starch, cellulose, chitosan and seaweed extracts), lipids (e.g. beeswax, paraffin and shellac resin) and proteins (e.g. zein, wheat gluten and whey protein) (Hassan et al., 2018).

Ebrahimi and Rastegar (2020) applied the edible coating made from guar gum enriched with *Spirulina platensis* in mango and evaluated its preservative effect. They observed that the enriched coatings reduced the respiration rate and weight loss, obtained low color alteration of the mango peel during storage, found greater firmness in the fruit compared to the control, and even showed a greater amount of total phenolic compounds and antioxidant activity, demonstrating its potential applicability in food preservation.

Therefore, this study aims to evaluate the functionality and effectiveness of coatings made from starch obtained from mango seed kernels, added with glycerol and sorbitol, applied to mangoes stored under controlled temperatures.

Material and methods

Preparation of Filmogenic Solutions and Coating of Fruits

The starch extraction followed the methodology of Van Hung et al. (2017), with adaptations. The kernels (900 g) were immersed in a solution containing 4.5 g of sodium metabisulfite at 1% (w/v) in 2.250 L of

refrigerated distilled water (5°C) and left to rest for 24 hours. After this period, the kernels were removed from the solution and blended in an industrial blender with 4.5 L of distilled water at maximum speed for approximately 3 minutes. The starch suspension was left to rest for 24 hours at 10°C. After this time, the supernatant was discarded, and three washings with 1 liter of distilled water each were carried out, followed by decantation. The starch sediment was then recovered by centrifugation at 6000 rpm for 10 minutes. The material was transferred to aluminum trays and dried in an oven at 50°C for 12 hours, with the chosen temperature and time selected not to affect the final product.

For the coating preparation, six solutions with different concentrations of starch extracted from mango seed kernels (MSK) were formulated. In three of the formulations, glycerol (liquid, Synth brand) was added, while in the other three, sorbitol (powder, Fillovita brand) was added. Thus, six filmogenic solutions with different MSK concentrations (1%, 2%, and 3%) were prepared. The filmogenic solutions were formulated with three concentrations of starch, corresponding to 10, 20, and 30 grams of starch per 1000 mL of distilled water, with 1% (10 mL) glycerol. For sorbitol, the same starch concentrations (1, 2, and 3%) were used in 1000 mL of distilled water, with the addition of 1% (10 g) plasticizer for each concentration. The solutions were heated to $70 \pm 5^\circ\text{C}$ for 15 minutes to ensure complete starch gelatinization, and then left to rest until they cooled to room temperature.

After preparing and cooling the solutions, the fruits were immersed in 1%, 2%, and 3% MSK solutions with glycerol and 1%, 2%, and 3% MSK solutions with sorbitol for 1 minute, then placed on a bench under artificial ventilation for 30 minutes to remove excess solution. Subsequently, the fruits were kept at room temperature to drain the excess coating and allow the fruits to dry for four hours.

As a control strategy and to assess the effectiveness of the coatings, some fruits were left uncoated, serving as control samples.

The coated and uncoated fruits were stored and refrigerated at 13°C for 30 days, with analyses conducted every 5 days on: mass, absorbance difference index (DA Index), longitudinal and transverse diameter, firmness, color loss of the skin and pulp, total soluble solids, pH, and total titratable acidity.

Physical, Chemical, and Physicochemical Evaluations

The masses of the fresh fruits were determined using an analytical balance with a precision of 0.0001 g (model AS-200 Ohaus Analytical Standard). The results were expressed in grams.

The color coordinates of the fruit skin and pulp were obtained from the averages of two readings at equidistant points on each fruit using a portable digital colorimeter from Konica Minolta DP-400. The coordinates included: L, which represents lightness (brightness or reflectance, where zero is dark/opaque and 100 is white); a^* (negative values correspond to green intensity and positive values to red intensity); and b^* (negative values correspond to blue intensity and positive values to yellow intensity). From these values, the browning indexes (BI) (Pathare; Opara and Al-Said, 2013) for skin and pulp were determined using (Equation 1) and (Equation 2):

$$BI = 100 \times \frac{(X-0.31)}{0.172} \quad (1)$$

$$X = \frac{(a^* + 1.75 L^*)}{(5.645 L + a^* - 3.012b^*)} \quad (2)$$

Where: L^* , a^* and b^* = described above.

The Absorbance Difference Index (ADI) was obtained using a portable spectrophotometer called DAE meter® (Turoni/Italy), based on the difference between absorbance values measured at 670 and 720 nm (Noferini et al., 2009).

The mass loss (ML) of the fruits was determined using a semi-analytical balance with a precision of 0.01 g. The longitudinal (LD) and transverse (TD) diameters of the fruits were measured using a digital caliper (mm). Firmness was determined with the aid of a manual penetrometer Instruterm model PTR 100, with an 8 mm diameter probe, taking measurements on two opposite sides of the equatorial region of the fruit, where the epidermis was removed, and the results were expressed in Newtons (N).

The soluble solids content was measured using a digital refractometer, with the results expressed in °Brix (IAL, 2008). Titratable acidity (TA) was determined by titration with an alkaline solution of sodium hydroxide (NaOH 0.1 mol.L⁻¹), using a 1% alcoholic phenolphthalein solution as an indicator, with the results were expressed as a percentage of citric acid (IAL, 2008). The pH was determined in mashed and homogenized mango pulp using a pH meter (IAL, 2008).

Statistical Analysis

The experimental design was a completely randomized 6 x 7 factorial scheme, analyzing six starch coatings extracted from mango seed kernels (MSK) at concentrations of 1%, 2%, and 3%, with glycerol and 1%, 2%, and 3% starch plus sorbitol, across seven time periods (0, 5, 10, 15, 20, 25, and 30 days) under refrigerated storage at 13°C. Means were compared using Tukey's test at 5% probability with the software Sisvar, Version 5.6 (Ferreira, 2019).

Results and discussion

The treatments had highly significant effects ($p < 0.01$) on the variables mass loss (PM), firmness, absorbance difference index (ADI), skin browning index (BI_{skin}), soluble solids (SS), titratable acidity (TA), and pH. These results indicate that the different treatments applied significantly influenced these quality characteristics of the product. On the other hand, the variables longitudinal diameter (DL), transverse diameter (DT), and pulp browning index (BI_{pulp}) were not significantly affected by the treatments, suggesting that these parameters did not vary significantly between the different treatments.

The storage period had a highly significant impact ($p < 0.01$) on the variables LD, TD, firmness, ADI, BI_{skin} , BI_{pulp} , SS, and pH, showing that the storage time substantially influences product quality. However, titratable acidity (TA) was not significantly affected by the storage period, which may indicate a relative stability of this characteristic over time.

The interaction between treatments and the storage period was significant only for the PM variable ($p < 0.01$), suggesting that the effect of the treatments on mass loss varied according to the storage time. For the other variables, the T (Treatments) x P (Period) interaction was not significant, indicating that the effects of the treatments did not differ across the different storage periods.

These results show that both treatments and storage period play critical roles in determining product quality, but the effects are predominantly independent, except in the case of mass loss. The absence of significant interactions for most variables suggests that treatment practices can be adjusted independently of the storage period to optimize the final product quality.

The results of the mass loss of the control fruits and the coated fruits are presented in Figure 1. It is possible to observe that the mass loss gradually increased throughout the entire storage period for all treatments.

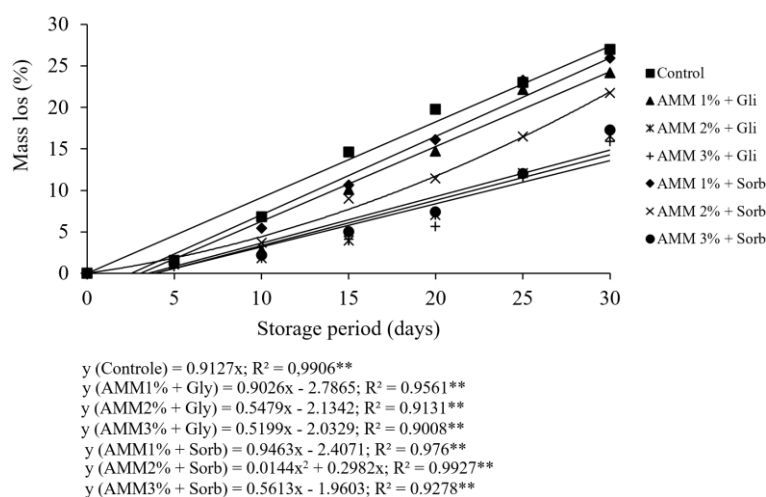


Figure 1. Mass loss of 'Tommy Atkins' mangoes coated with formulations based on different concentrations of starch from mango almond mesocarp (AMM) added with glycerol (Gly) or sorbitol (Sorb) and stored for thirty days under refrigeration.

This increase in mass loss was greater in the control fruits, with AMM 1% + Gly, AMM 1% + Sorb, and AMM 2% + Sorb. On the other hand, the fruits coated with AMM 2% + Gly, AMM 3% + Gly, and AMM 3% + Sorb showed less mass loss until the last day of storage. Costa et al. (2016), in a study with mangoes coated with different concentrations of starch, also found that during the storage of the fruits, there was mass loss; however, the fruits coated with higher concentrations of starch were able to delay mass loss for a longer period. These results are in agreement with those obtained in this research, as according to the percentages shown in the graph in Figure 1, the coatings with higher concentrations of AMM 2% + Gly, AMM 3% + Gly, and AMM 3% + Sorb, up to the end of the storage period, had mass loss below 15%.

Saekow (2019), analyzing the mass loss of persimmon and tomato coated with and without zinc oxide nanoparticles based on carboxymethylcellulose, found that the mass loss of the fruits increased for all treatments during the storage time, similar to the results presented in this study.

García, Martino and Zaritzky (1998) found that coatings made with high-amylose starch better preserved the weight loss and firmness of strawberries for longer periods than did medium-amylose starch coatings. Likewise, these authors observed that coatings plasticized with sorbitol exhibited better water vapor barrier capacity than those containing glycerol. In this sense, Sagnelli et al. (2017), report that the use of amylose-only starch obtained from transgenic plants to obtain starchy materials with improved properties.

Other important quality attributes of mangoes are their diameters, as these parameters are crucial for assessing the stage of ripeness. According to graphs a and b in Figure 2, a slight reduction in the longitudinal diameter was observed for all treatments (control and coatings) throughout the storage period. However, this variation is not significant enough to affect the overall quality of the fruits.

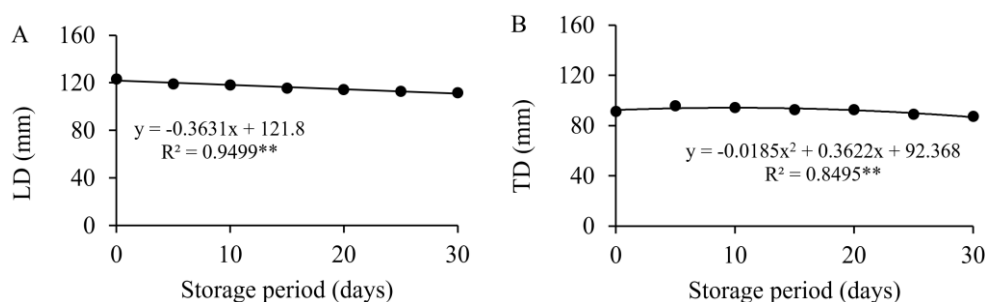


Figure 2. Longitudinal diameter (A) and transverse diameter (B) of 'Tommy Atkins' mangoes stored for thirty days under refrigeration after being coated with formulations from different concentrations of mango almond starch.

The observed mass loss impacted the fruit dimensions, with the variations in both longitudinal and transverse diameters being minimal for both the control fruits and those coated with starch extracted from the mango seed almond (AMM) throughout the storage period.

All fruits coated with AMM maintained higher firmness compared to the control fruits, regardless of the concentration. However, fruits coated with AMM 3% + Sorb exhibited a statistically significant difference in firmness compared to the control fruits and all other treatments.

Fruit firmness decreased during storage for all treatments, as shown in graph B in Figure 3, for both control and AMM-coated fruits, regardless of the concentrations and type of plasticizer. Results also found by Costa et al. (2016), when coating mangoes of the 'Palmer' variety with different concentrations of cassava starch. They noticed that regardless of whether the fruits were coated or not (control), there was a loss of mass and, consequently, a loss of fruit firmness.

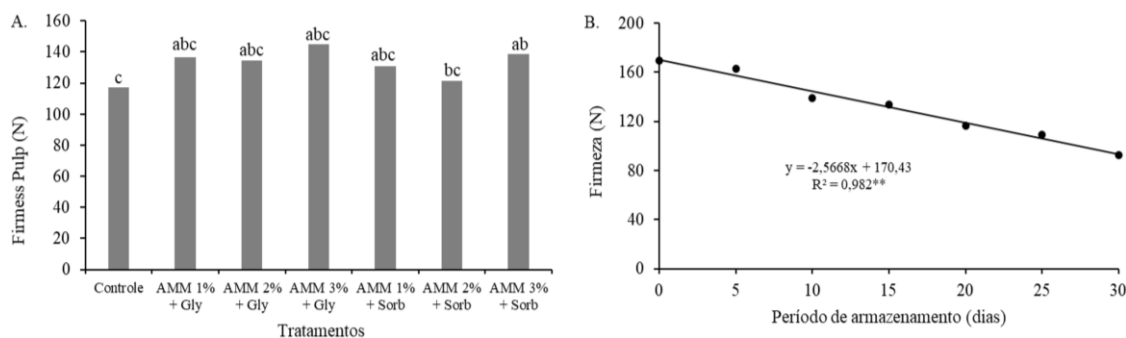


Figure 3. Firmness of 'Tommy Atkins' mangoes coated with formulations from different concentrations of starch from mango almond mesocarp (AMM) added with glycerol or sorbitol (A); and stored for thirty days under refrigeration (B).

Averages followed by the same letters do not differ from each other using the Tukey test at 5% probability.

Nawab, Alam and Hasnain (2017), evaluating tomatoes coated with a starch-based coating from the seed kernel of the 'Chaunsa' mango variety, added with the plasticizers glycerol and/or sorbitol, found similar results, with the firmness of the fruits decreasing during processing. storage in fruits with cover and control. However, the covered fruits maintained their firmness for a longer period. These results corroborate those observed in this research.

Even in the face of reduced firmness, the application of starch extracted from mango seed kernels in the formulation of coatings can be used as a post-harvest technology, as it delayed the respiration and ripening process, resulting in an extension of the storage period (Parreidt et al., 2019). According to Sapper and Chiralt (2018), starch-based edible coatings provide a barrier against water vapor and gases and therefore lower levels of O₂ and higher levels of CO₂ within the fruit, which helps to control the product's enzymatic activities, helping to maintain the firmness of the coating during storage. Furthermore, non-toxic antifungal compounds incorporated into edible coatings prevent fungal lesions, which is one of the main causes of fruit and vegetable interference.

Averages followed by the same letters do not differ from each other using the Tukey test at 5% probability.

The absorbance difference index (ADI) is a parameter that evaluates the fruits according to the degradation of chlorophyll, with the ripening of the fruits. In this case, analyzing the graphs in Figure 4, with the ADI correlated with the treatments used, a significant difference can be seen between the treatments AMM 3% + Gly and AMM 3% + Sorb when compared with the control fruits, while the other treatments there was no significant difference between these and the control. The smaller variation in the DA index for mangoes was not significant, which may be related to smaller changes in the green color of the peel, a factor observed by Costa et al. (2017), when analyzing the different stages of ripeness of 'Tommy Atkins' mangoes using the ADI.

In Figure 4b, according to the interaction of the ADI and the storage period, it can be seen that as the days passed, the ADI values decreased, a consequence of the ripening of the fruits, this is because the chlorophyll was degraded, being one of the main processes responsible for changes in the fruit pericarp (Sousa et al., 2021).

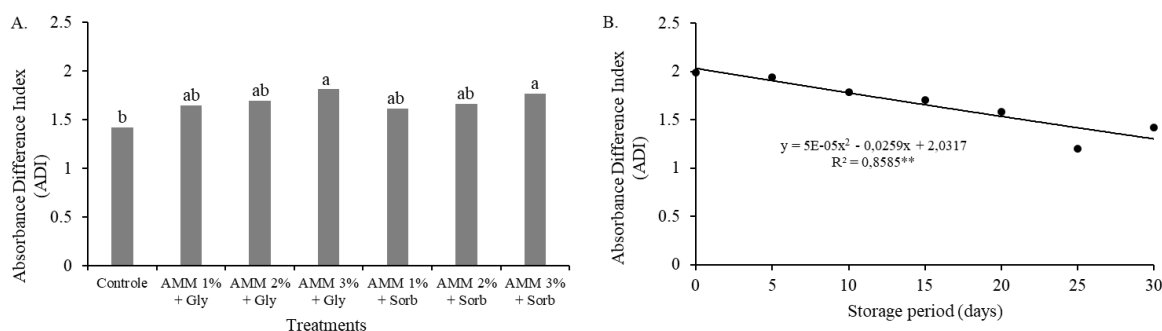


Figure 4. Absorbance Difference Index (ADI) of 'Tommy Atkins' mangoes coated with formulations from different concentrations of mango almond starch (AMM) added with glycerol or sorbitol (A); and stored for thirty days under refrigeration (B).

Considering the color coordinates (L, a*, b*) together, the browning index of the fruit peel, as shown in Figure 5, revealed a significant difference between the control fruits and those coated with AMM 3% + Gly and AMM 3% + Sorb. However, when comparing the control fruits with the other treatments, there was no significant variation, nor was there a significant difference among the coatings. Analyzing the graph in Figure 5b, the browning index showed a gradual increase throughout the storage period.

Thus, it can be observed that the control fruits with the lower coating concentrations experienced greater peel browning by the end of storage, indicating a degradative effect that could influence consumer acceptance.

Averages followed by the same letters do not differ from each other using the Tukey test at 5% probability.

Given the impact of fruit color on quality and market value, this characteristic is crucial in determining consumer acceptance. Freshly harvested fruits typically have a shiny and lustrous surface, but this appearance can be significantly diminished due to weight loss, surface dehydration, and moisture loss during post-harvest handling (Pathare et al., 2013).

The initial green color of fruits is primarily due to the presence of chlorophyll. As fruits mature, chlorophyll is broken down while other pigments are formed from colorless precursors (like phytoene) into β -carotene (orange), lycopene (red), carotene (light yellow), xanthophylls, and carotenoids (yellow) (Su et al., 2015). An increase in the a* value during storage may be attributed to higher respiration rates and stimulation of enzymatic activities, including browning reactions and other processes responsible for chlorophyll degradation. A decrease in a* (more green than red) and b* (more blue than yellow) in coated samples throughout storage may suggest a delay in the mango ripening process.

Previous studies have also shown that edible coatings can slow pigment degradation and prevent the development of undesirable colors by affecting the permeability of the fruit's epicarp, thus modifying gas exchange and reducing oxidative processes (Lo'ay & Taher, 2018).

The darkening of the pulp was not affected by the coatings, showing a natural increase during the storage period (Figure 5c), which could influence the inhibition of the ripening and senescence processes in mango fruits (Tahir et al., 2020). Similar behavior was observed by Khaliq et al. (2016), where the control treatment, when compared to the use of edible coatings, demonstrated a delay in senescence and better color retention in mango fruits coated with gum arabic. This was also noted by Miguel et al. (2013) in 'Palmer' mangoes stored at low temperatures for twenty-one days, and by Costa et al. (2017) in studies on the shelf life of 'Tommy Atkins' mangoes stored in XTend packaging.

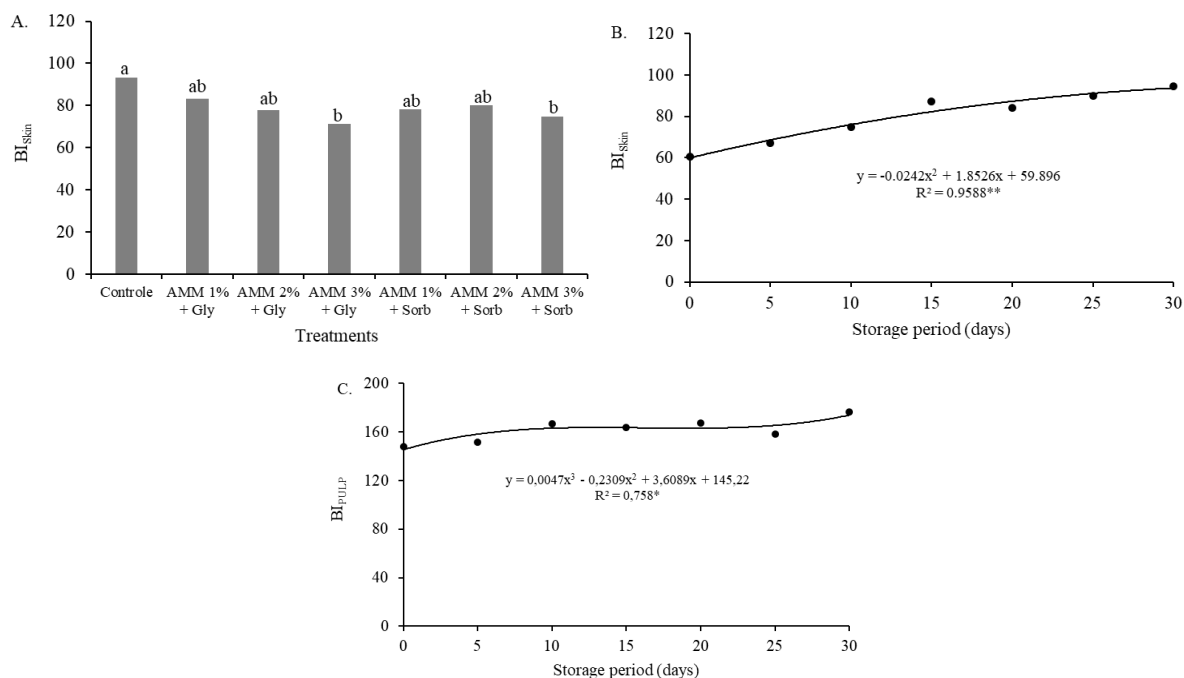


Figure 5. Browning Index (BI) of the skin of 'Tommy Atkins' mangoes coated with formulations based on different concentrations of starch from mango seed almonds (AMM) with added glycerol or sorbitol (A); stored for thirty days under refrigeration (B); and of the pulp of 'Tommy Atkins' mangoes stored for thirty days under refrigeration (C).

In this study, the soluble solids (SS) content, titratable acidity, and pH were evaluated as indicators of the metabolic state of mangoes and as factors influencing fruit quality. The effects of coating mangoes with formulations containing different concentrations of mango starch and almond starch, with added glycerol or sorbitol, and storing them for thirty days under refrigeration are described in Figure 6.

Averages followed by the same letters do not differ from each other using the Tukey test at 5% probability.

In Figure 6a, the variation in total soluble solids content showed significant differences among treatments. Fruits coated with AMM 3% + Gly presented lower values and differed statistically from the control and from treatments such as AMM 2% + Sorb, which exhibited higher values. The remaining treatments showed intermediate behavior, not differing significantly from either group.

Based on Figure 6b, it can be observed that throughout the storage period, the total soluble solids content gradually increased, reaching a value above 14°Brix after 30 days of storage. The coatings have the potential to reduce fruit respiration, contributing to the control of the gradual increase in soluble solids content in coated fruits (Oliveira et al., 2020). According to Batista et al. (2015), the soluble solids content is also related to the mango variety and can vary depending on the cultivar, such as in Haden, Kent, Tommy Atkins, Palmer, Keitt, Espada, and Rosa mangoes, which have total soluble solids content ranging from 12 to 18.1°Brix. The average values reported for 'Tommy Atkins' mangoes are close to those observed in this study.

Titratable acidity is expressed as a percentage of citric acid. As shown in Figure 6c, the fruits coated with AMM 3% + Gly have lower acidity levels, significantly differing from the fruits coated with AMM 1% + Gly, AMM 2% + Gly, and AMM 1% + Sorb. However, when statistically compared with the control fruits and those coated with AMM 2% + Sorb and AMM 3% + Sorb, no significant difference was found.

Looking at Figure 6c, it is clear that, even though there were significant differences between the treatments, the acidity of the fruits remained below 1.2% citric acid, indicating that the fruits, regardless of treatment, continued to have low acidity levels. The low storage temperatures and the coatings are factors

that contribute to a slow ripening process, causing the fruits to remain more acidic, as the acids were not degraded as quickly, or possibly not degraded at all depending on the evaluation period, which may explain these results (Sousa et al, 2021).

Aires et al. (2022), in their study on the use of carnauba wax coating added with kaolin clay for the preservation of 'Palmer' mangoes, also obtained similar results, where the acidity did not decrease during the thirty-five days of storage. Fai et al. (2015) found different results in a study with carrots coated with a film made from fruit and vegetable residues, observing that titratable acidity increased but slowly decreased during storage. Similar results to those of this experiment were found by Sogvar et al. (2016) in strawberries coated with nanoparticles, where the titratable acidity decreased with and without coating.

pH is a parameter that correlates with titratable acidity; as one increases, the other decreases, as shown in the Figure 6d. In this case, it was found that the fruits coated with AMM 3% + Gly had a pH above 3, which was higher than that of the other treatments. However, statistically, there was no significant difference between the AMM 3% + Gly treatment and the control fruits or those coated with AMM 3% + Sorb. Likewise, there was no significant variation between the control fruits and the other treatments with AMM 1% and 2% + Gly and AMM 1%, 2%, and 3% + Sorb. This indicates that while the AMM 3% + Gly treatment resulted in slightly higher pH values, these differences were not statistically significant when compared to the control or other treatments. The omission of AMM 3% + Gly in earlier discussions may lead to an incomplete interpretation of the data, underscoring the importance of considering this treatment as statistically equivalent to the control fruits.

In Figure 6d, it can be observed that the pH showed only a slight variation. This is because, according to the acidity results correlated with the treatments, the fruits remained acidic, indicating that the degradation of acids occurred gradually. This variation had minimal impact on the pH results. In a study with 'Palmer' mangoes coated with higher concentrations of kaolin clay, Aires et al. (2022) found that the pH levels remained low, which was correlated with the fruit's acidity and the reduction in respiration due to both the coatings and storage.

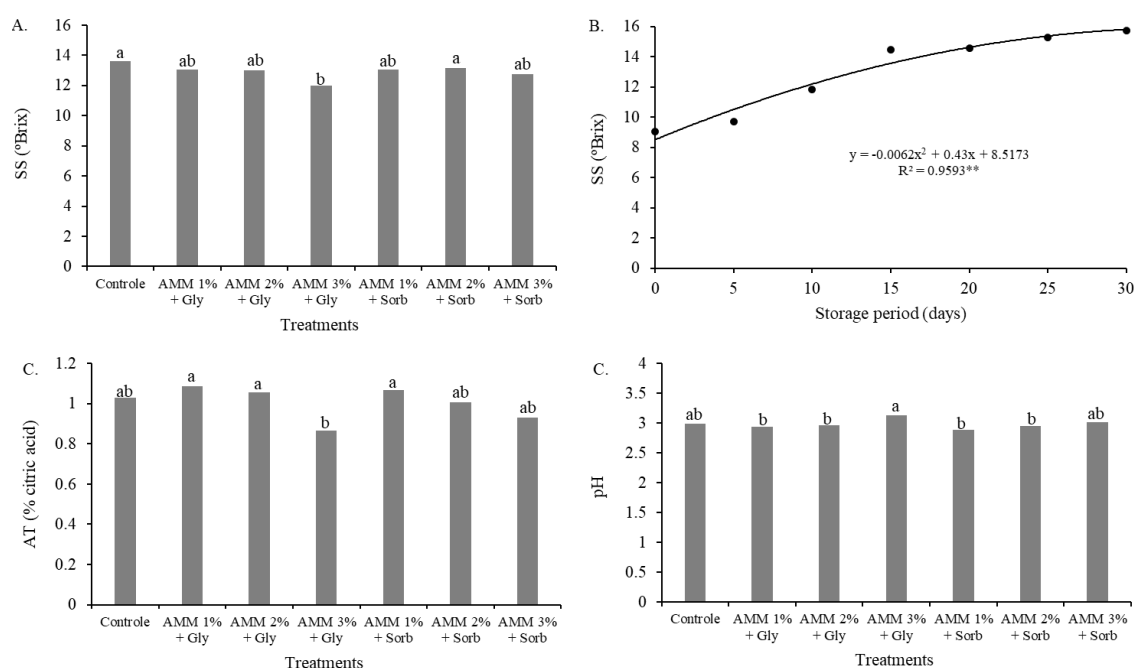


Figure 6. Soluble solids (SS) of 'Tommy Atkins' mangoes coated with formulations from different concentrations of mango almond starch (AMM) added with glycerol or sorbitol (A); and stored for thirty days under refrigeration (B); Titratable acidity (TA) of 'Tommy Atkins' mangoes coated with formulations from different concentrations of mango almond starch (AMM) added with glycerol or sorbitol (C); and Hydrogen potential (pH) of 'Tommy Atkins' mangoes stored for thirty days under refrigeration (D).

Which correlates pH with the refrigerated storage period and comparing the first day of analysis (5th day) with the last day of storage (30th day), a significant difference is observed. This demonstrates that the storage period influenced the pH of the fruits, reflecting the reduction in acids. According to Alonso-Salinas et al. (2024), pH variations can be attributed to the initial degradation and subsequent synthesis of organic acids with different ion dissociation potentials, with lower pH values being associated with a more advanced stage of ripening.

Nunes et al. (2017) obtained results ranging from 5.34 to 5.44 in their work with cassava starch coating on Formosa papaya, and these results did not vary or differ significantly throughout the storage period. Barros et al. (2019), in their studies on the use of alternative coatings for post-harvest conservation of papaya, observed a slight increase in pH across all treatments. However, when analyzing the storage period, there was no significant difference, with these results being similar to those found in the present study.

A similar trend was observed by Abugoch et al. (2016), who used chitosan incorporated with quinoa protein and sunflower oil for improving the shelf life of blueberries. They found that the control fruit showed higher pH value than the coated samples. The higher SS value in control after 21 days of storage could be attributed to fast acid metabolism which converted starch and acid to sugar, hence resulting in higher pH and increase of SS (Duan et al., 2011).

Conclusion

Films based on starch extracted from 'Tommy Atkins' mango seeds added with plasticizers (glycerol and sorbitol) proved to be effective in post-harvest preservation of mangoes, maintaining fruit firmness, reducing mass loss and delaying browning.

The higher concentrations of starch (2% and 3%) associated with glycerol and sorbitol were especially effective in extending the shelf life of the fruits during 30 days of refrigerated storage. Therefore, these biodegradable films present themselves as a promising and sustainable alternative to conventional synthetic coatings, with potential for industrial use in fruit preservation.

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