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Postharvest conservation of ‘Prata’ bananas with a starch-based coating derived from straw potato processing

Conservação pós-colheita de banana ‘Prata’ com revestimento à base de amido proveniente do processamento de batata-palha

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ABSTRACT

In the production process of straw potatoes, a large amount of residual starch from the washing stage can be used to formulate biodegradable materials. The present study evaluated the use of a coating made from this residual starch in the postharvest conservation of ‘Prata’ bananas during storage (23.5±0.5ºC and 73.3±2.4% RH). The following postharvest treatments were performed: 1) control; 2) immersion in a solution (82% residual starch, 13% glycerol, and 5% acetic acid at 4.5% w/v). Samples were characterized every two days for mass loss, L* value, hue angle, chroma, firmness, soluble solids, titratable acidity, and pH. The coated fruits showed greater mass loss compared to the control from the fourth day onwards, without changes in the appearance and quality of the banana. A lower hue angle and higher L* value and chroma were observed in the control fruits compared to the coated ones. A more pronounced linear reduction in firmness was observed in the control fruits compared to the coated bananas. The coating was effective in reducing the soluble solids content of the fruits. Therefore, the starch, acetic acid, and glycerol coating applied to the banana peel proved to be effective in delaying the ripening of the fruits for 8 days.

Keywords: *Musa* spp.; Biodegradable Material; Potato Starch; Shelf Life; Quality.

RESUMO

No processo de produção de batata palha, há uma grande quantidade de amido residual da etapa de lavagem, que pode ser aproveitado para formulação de materiais biodegradáveis. Portanto, objetivou-se utilizar um revestimento obtido a partir desse amido residual na conservação pós-colheita de banana 'Prata' durante o armazenamento (23,5±0,5ºC e 73,3±2,4% UR). Os tratamentos pós-colheita foram: 1) controle; 2) imersão em solução (82% amido residual, 13% glicerol e 5% ácido acético à 4,5% m/v). As análises foram realizadas a cada 2 dias: perda de massa fresca, valor L*, ângulo hue, croma, firmeza, sólidos solúveis, acidez titulável e pH. Os frutos revestidos apresentaram maior perda de massa em relação ao controle, a partir do quarto dia, mas não comprometeu a aparência e a qualidade da banana. Observou-se menor ângulo hue e maior valor L* e croma nos frutos controle comparados aos com revestimento. Houve redução linear mais acentuada da firmeza nas bananas controle em relação as revestidas. O revestimento foi eficiente em reduzir o teor de sólidos solúveis. Conclui-se que o revestimento de amido, ácido acético e glicerol aplicado na casca das bananas mostrou-se eficaz em retardar o amadurecimento, por 8 dias.

Palavras-chave: *Musa* spp.; Material Biodegradável; Fécula de Batata; Vida de Prateleira; Qualidade.

INTRODUCTION

The growing concern over the depletion of fossil resources, coupled with increasing environmental awareness, has driven the search for new methodologies for the production of more sustainable biopolymers. This approach can help reduce the production costs of biopolymers and, consequently, mitigate environmental risks, as improper waste management can lead to severe environmental damage (Nunes *et al.*, 2021). Large amounts of waste are generated in the food industry, which can harm the environment if not properly reused or treated. In the production process of straw potatoes, a large amount of residual starch from the washing stage can be used to formulate biodegradable materials.

Starch is used in edible films and coating as it has the capacity for forming colorless, tasteless, and translucent layers with properties similar to synthetic polymers. Starch is a natural polymer derived from plants and is biodegradable. It has a high water-binding capacity, is non-toxic, and is relatively inexpensive. The starch-based edible films and coatings have properties similar to synthetic polymers, such as moisture resistance, heat resistance, and flexibility. These properties make starch-based edible films and coatings suitable for use in food packaging and preservation (Majeed *et al.*, 2023).

However, starch films are highly sensitive to water and exhibit limited water vapor barrier properties and mechanical strength. Various compounds, such as plasticizers, lipids, or other polymers, have been incorporated to improve the functional properties of starch-based films/coatings (Sapper; Chiralt, 2018). Potato starch can be a viable alternative for producing biodegradable coatings aimed at preserving the postharvest quality of various fruits, including bananas.

Bananas are the most consumed fresh fruit in Brazil and globally. They hold significant economic importance in tropical countries and are highly appreciated for their taste, ease of consumption, low cost, and nutritional benefits, being a source of energy, vitamins, and minerals. In Brazil, the largest banana-producing states - São Paulo, Bahia, Minas Gerais, Santa Catarina, and Pará - account for 60.1% of national production. The Brazilian banana production is almost entirely directed to the domestic market due to the large population and high national per capita consumption (Martins; Turco, 2019).

Banana is a climacteric fruit generally harvested in its mature green state. It is vulnerable to rapid deterioration because it is a living product with ongoing metabolic activities during storage. At a room temperature, the shelf life of the banana is very limited. Thus, edible coatings appear as an adequate alternative in the preservation of fruits in the fresh state (Tchinda *et al.*, 2023).

Therefore, delaying fruit ripening through postharvest techniques can be a valuable strategy to extend shelf life while maintaining quality. In light of this, the present study aimed to use a coating developed from residual starch from the processing of straw potatoes to preserve the postharvest quality of 'Prata' bananas during storage (23.5±0.5ºC and 73.3±2.4% RH).

MATERIAL AND METHODS

The residual starch was obtained by centrifugation after washing peeled 'Atlantic' potatoes used in the production line of straw potatoes at a food company of Pouso Alegre/MG. The experiment was performed in the Federal Institute of Education, Science, and Technology of South of Minas Gerais, Brazil.

The residual starch was washed, filtered using a vacuum pump, and dried in an oven at 70°C for 7 hours. After this step, the moisture content was 9.7%, determined using a thermogravimetric balance. The formulation was defined based on preliminary tests, and the following composition was selected for the study: 82% residual starch, 13% glycerol, and 5% acetic acid at 4.5% w/v. After weighing and diluting the ingredients in water at a w/v ratio of 0.045 g/mL, the solution was heated to 70°C for 20 minutes under constant manual stirring, which was maintained for an additional 2 minutes after the beginning of the gelatinization process. The solution was cooled in an ice bath to 25°C.

The ‘Prata’ bananas (color stage 2, meaning green with yellow traces), in the mature stage, were obtained from Pedralva/MG. The banana bunches were divided into bouquets of three fruits each. These were immersed in the solution (82% residual starch, 13% glycerol, and 5% acetic acid at 4.5% w/v) for 30 seconds, using a hook attached between the peduncles of the bouquets to ensure complete coating of the fruits.

After immersion, each bouquet of three fruits was hung on a support using the hook. Both the control (without coating) and the starch-coated fruits were stored for 8 days (23.5±0.5ºC and 73.3±2.4% RH). The analyzes were performed every two days.

Fresh mass loss (%) was determined by calculating the difference between the initial mass of the bouquets of three fruits and that obtained after each evaluation date, using a semi-analytical balance (Shimadzu), with an accuracy of 0.01 g.

The L* value, hue angle, and chroma were measured in two opposite points of the peel in the equatorial region of the three fruits of each repetition, using a colorimeter (Minolta - CR400), with D_{65} illuminant and 2° observer angle, according to the CIE L*a*b* color space (Minolta, 1998).

Firmness (N) was determined by the maximum penetration force, using a penetrometer (Instrutherm - PTR 300), with a cylindrical probe (8 mm diameter), adapted to a support with a lever. Measurements were taken in the median region of the fruit.

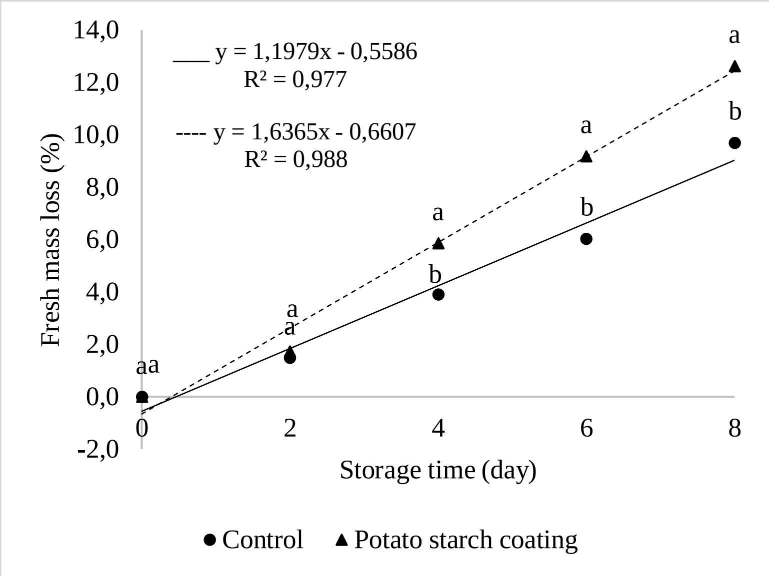
The soluble solids (ºBrix) were determined using a digital refractometer (Atago - Smart-1) with automatic temperature compensation at 25°C. The titratable acidity (% malic acid) was determined by titration using sodium hydroxide solution 0.1 mol/L and the phenolphthalein as indicator and the pH of the pulps was determined using a pH meter (Tecnal - Tec-3MP) (Instituto Adolfo Lutz, 2008).

The experiment was conducted in a completely randomized design with three replications. The treatments were arranged in a 2 x 5 factorial scheme, consisting of 2 levels of the coating factor (without and with) and 5 levels of the storage factor (0, 2, 4, 6 and 8 days). Statistical analyses were performed using the Sisvar program (Ferreira, 2011).

RESULTS AND DISCUSSION

The fresh mass loss of the bananas was significantly affected by the interaction between the coating and storage time (Figure 1). Starting from the fourth day, there was greater mass loss in the coated fruits compared to the control group. Costa *et al.* (2019) reported that 'Prata Anã' bananas exhibited linear mass loss over 12 days of storage, regardless of the coating used (cassava starch and pectin), indicating that the coatings studied were not effective as water vapor barriers. Similarly, Silva *et al.* (2011) found that gelatinized starch coatings did not prevent moisture loss in 'Prata' bananas stored under refrigeration (8-10ºC and 50-65% RH) for 7 days.

Figure 1 - Average values, regression equation and coefficient of determination of fresh mass loss (%) of 'Prata' bananas, with and without coating of residual starch, glycerol and acetic acid, and stored (23.5±0.5 ºC and 73.3±2.4% RH), for 8 days.



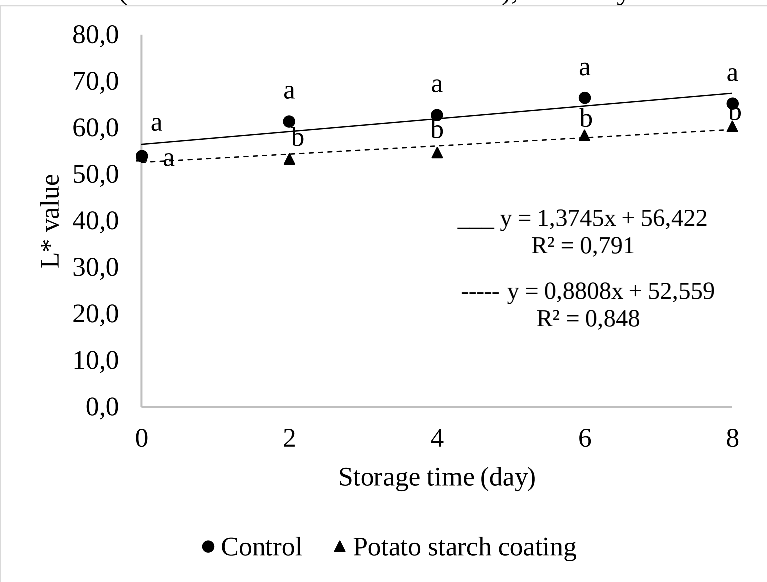
Means followed by the same letter, within each time, do not differ statistically from each other, using the Turkey test, to 5%.

Nunes *et al.* (2004) also observed that cassava starch had low effectiveness in preventing fresh mass loss when applied to peaches. While water loss up to 10% is considered acceptable, it should be avoided if it causes shriveling or wrinkling of the fruit (Chitarra; Chitarra, 2005). In the present study, despite the mass loss, no shriveling was observed at the end of the storage period, with no changes in the appearance of the bananas.

Ballesteros-Mártinez, Pérez-Cervera e Andrade-Pizarro (2020) investigated the effect of different plasticizer concentrations (glycerol and sorbitol) on the mechanical, optical, and barrier properties of sweet potato starch films for coating and food packaging applications. The authors reported that increasing the plasticizer concentration in the film suspension resulted in higher water solubility, elongation, and water vapor permeability of the films.

A significant interaction between coating and storage time was observed for the L* color parameter (Figure 2). From the second day of storage, the peel of the control fruits showed a higher L* value, indicating that the bananas were lighter compared to the coated fruits (Figure 2), which ranges from zero (black) to 100 (white). Oliveira *et al.* (2018) reported significant changes in the L* value and chromaticity of banana peels over time, with values ranging from 57.07 and 40.79 at the beginning of the experiment to 57.27 and 41.09 after 10 days of storage, respectively.

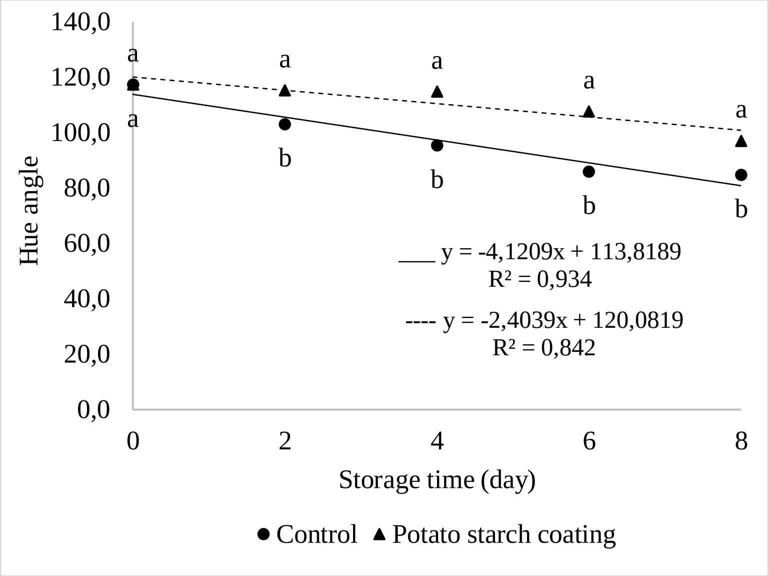
Figure 2 - Average values, regression equation and coefficient of determination of L* value of 'Prata' bananas, with and without coating of residual starch, glycerol and acetic acid, and stored (23.5±0.5 ºC and 73.3±2.4% RH), for 8 days.



Means followed by the same letter, within each time, do not differ statistically from each other, using the Turkey test, to 5%.

The hue angle of banana peels was significantly affected by the interaction between the coating and storage time (Figure 3).

Figure 3 - Average values, regression equation and coefficient of determination of hue angle of 'Prata' bananas, with and without coating of residual starch, glycerol and acetic acid, and stored (23.5±0.5 ºC and 73.3±2.4% RH), for 8 days.

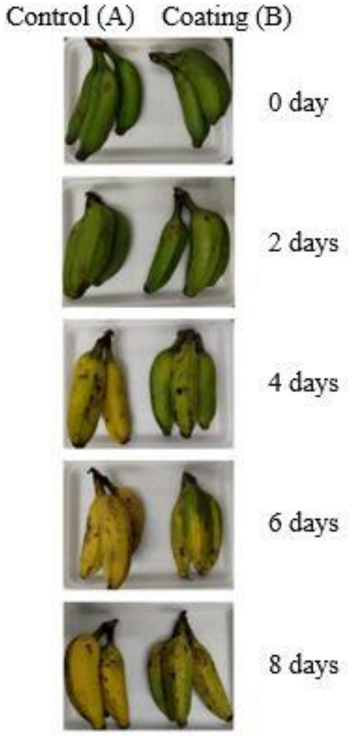


Means followed by the same letter, within each time, do not differ statistically from each other, using the Turkey test, to 5%.

In this study, a greater reduction in hue angle values was observed in the control bananas during storage (Figure 3), from 113.82° to 80.85°, indicating a shift in peel color to yellow, as 90° corresponds to yellow. In turn, the hue angle values of the coated bananas decreased linearly from 120.08° to 100.85° by the end of storage, effectively delaying the yellowing of the peel. Thakur *et al.* (2019) reported similar results, noting lower hue angle values for the control bananas compared to coated fruits, with a more significant reduction over 10 days of storage, from 117.51° to 86.91° for the control fruits.

The control fruits showed a yellow peel starting from the fourth day of storage when compared to the coated bananas (Figure 4), demonstrating that the coating was effective in delaying banana ripening. Furthermore, the invisibility of the coating, its adhesion to the fruit peel, and the homogeneous and continuous surface on the coated bananas were also observed.

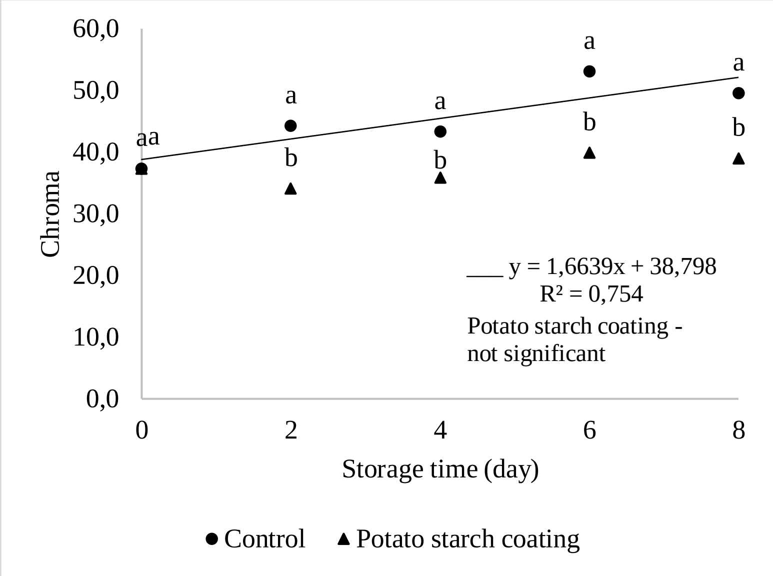
Figure 4 - Comparison between ‘Prata’ bananas, control (A) and with a coating (B) from residual starch, glycerol and acetic acid every 2 days, and stored for 8 days.



Oliveira *et al.* (2018) found similar results after 6 days of storage at 25±2°C and 65±5% RH, reporting a lower hue angle for the control peel of ‘Prata Anã’ bananas compared to all treatments with microalgae coatings. This reduction in hue angle is consistent with the natural ripening of the fruit, which changes from green to yellow, indicating that the control fruits had a yellowish color, while the coated fruits remained yellow-green at 8 days of storage.

Chroma was also significantly affected by the interaction between coating and storage time (Figure 5), with higher chroma values in the control fruits compared to the coated fruits from the second day of storage, indicating greater color intensity. Additionally, the control bananas exhibited a linear increase in chroma values throughout storage. Castricini *et al.* (2015) reported L*, hue angle, and chroma values of 59.34, 115.99º, and 40.24, respectively, for ‘Prata-Anã’ bananas at the time of commercial harvest (color stage 2), and values of 71.86, 92.71º, and 53.32 at maturity stage 6 (fully yellow peel), which are similar to those observed in the present study. The color results showed that the starch, glycerol, and acetic acid coating effectively delayed the yellowing of the banana peel.

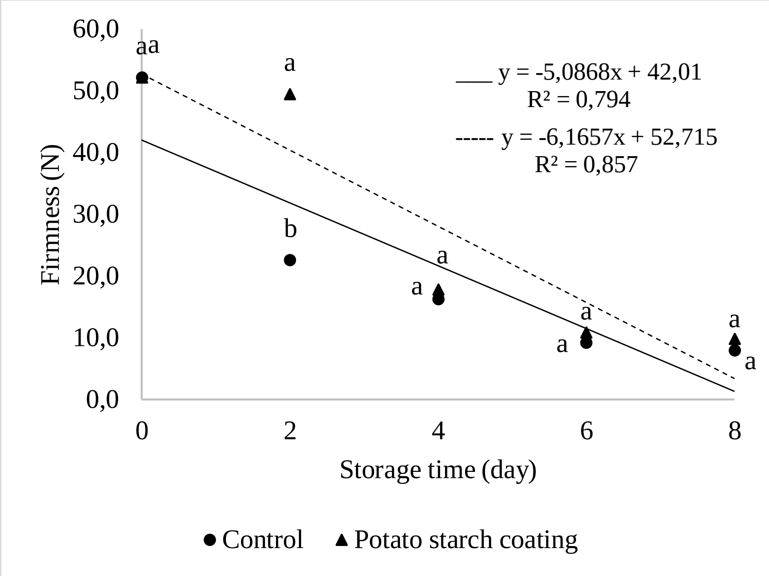
Figure 5 - Average values, regression equation and coefficient of determination of chroma (%) of 'Prata' bananas, with and without coating of residual starch, glycerol and acetic acid, and stored (23.5±0.5 ºC and 73.3±2.4% RH), for 8 days.



Means followed by the same letter, within each time, do not differ statistically from each other, using the Turkey test, to 5%.

According to Figure 6, on the second day of storage, coated bananas exhibited less firmness loss compared to the control, meaning they remained firmer. A more pronounced linear reduction in firmness was observed in the control bananas compared to the coated ones. Similarly, Thakur *et al.* (2019) reported a continuous and gradual firmness loss in both control and coated bananas during ripening. However, the treated fruit showed a slower rate of firmness loss compared to the control over the storage period until day 10. In contrast, control fruits experienced rapid softening within the first two days of ripening, maintaining a relatively constant softness in subsequent sampling times. According to the authors, better firmness retention in coated fruits indicated the coating's effectiveness in slowing down metabolic and enzymatic activities, resulting in a slower degradation of the pulp tissue.

Figure 6 - Average values, regression equation and coefficient of determination of firmness (N) of 'Prata' bananas, with and without coating of residual starch, glycerol and acetic acid, and stored (23.5±0.5 ºC and 73.3±2.4% RH), for 8 days.

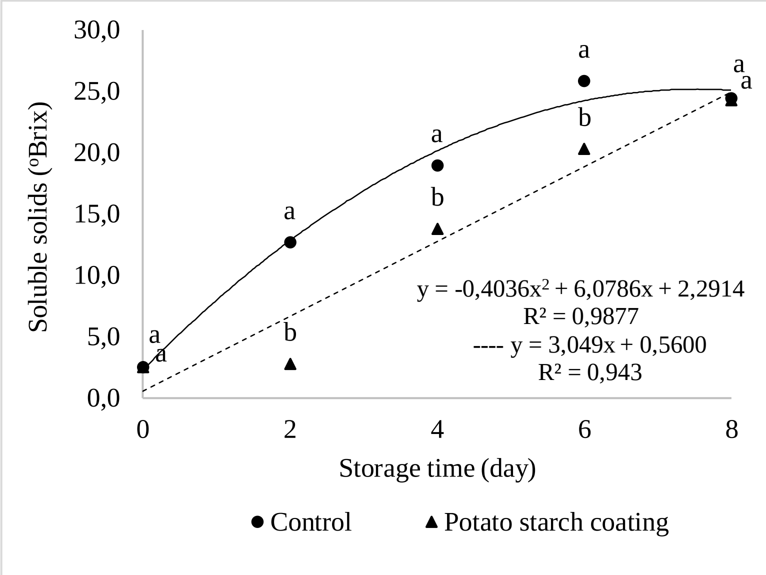


Means followed by the same letter, within each time, do not differ statistically from each other, using the Turkey test, to 5%.

Costa *et al.* (2019) found that bananas coated with cassava starch at 5% and 8% or pectin at 5% and 8% maintained greater firmness compared to the control during storage, suggesting that increasing the concentration of substances in the coatings may delay the senescence process in bananas and provide greater mechanical protection.

The control fruits had higher soluble solids content from the second to the sixth day of storage when compared to the coated bananas (Figure 7). However, both the control and coated fruits reached their maximum soluble solids content at different times, with maximum soluble solids for the control and coated fruits on the 6th and 8th days of storage, respectively. An increase in soluble solids was observed throughout the storage period, and the greater increase in the control bananas; soluble solids content could be associated with ripening. Tchinda *et al.* (2023) reported that the combination of aloe vera, starch, and Arabic gum extended the shelf life of banana by slowing down the chlorophyll degradation, the loss of firmness, the mass loss, and the synthesis of soluble solids. Coated bananas also showed the lowest soluble solids values compared to uncoated bananas.

Figure 7 - Average values, regression equation and coefficient of determination of soluble solids (ºBrix) of 'Prata' bananas, with and without coating of residual starch, glycerol and acetic acid, and stored (23.5±0.5 ºC and 73.3±2.4% RH), for 8 days.



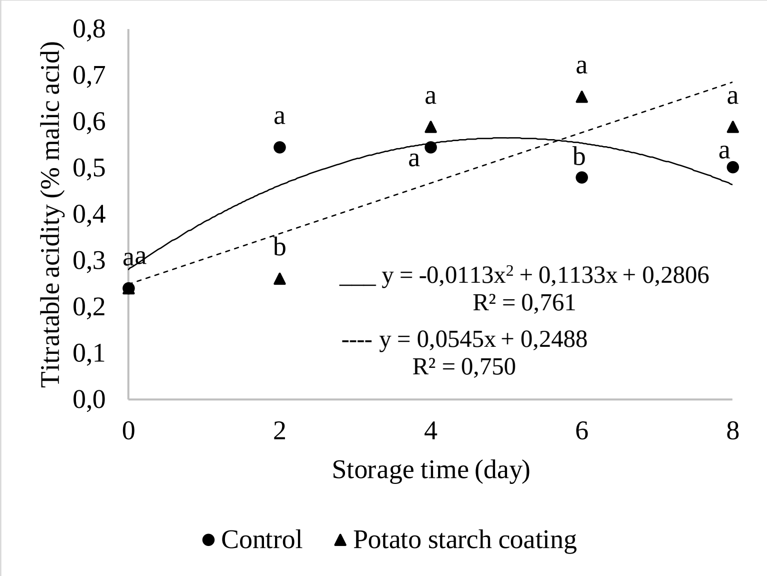
Means followed by the same letter, within each time, do not differ statistically from each other, using the Turkey test, to 5%.

Thakur *et al.* (2019) also reported an increase in soluble solids content during the storage of ‘Cavendish’ bananas coated with edible rice starch and sucrose esters over 12 days. Similarly, Oliveira *et al.* (2018) observed an increase in soluble solids content in the control ‘Prata Anã’ bananas compared to the other three microalgae-based coatings until the eighth day of storage (25±2°C and 65±5% RH). According to Passos *et al.* (2016), this behavior of soluble solids indicates that starch is hydrolyzed into sugars through primary metabolism, providing respiratory substrates for the biological activities of the fruit, which consequently leads to an increase in sweetness.

Additionally, the lower soluble solids content in the coated bananas was likely due to the slower metabolic activities of the fruit caused by the coating. Similar results, with a slower decrease in soluble solids, were found in previous studies on fruits coated with biopolymer coatings (Al-Qurashi *et al.*, 2017; Soradech *et al.*, 2017).

There was a significant interaction between coating and storage time for the titratable acidity (Figure 8). The banana coating initially delayed the titratable acidity levels. The control fruit reached a peak of malic acid in a shorter time compared to the coated fruits, followed by a decrease in acidity. In contrast, the coated fruits maintained higher acidity levels without the typical reduction seen during banana ripening. Therefore, the control fruit showed the end of the ripening process, which was not observed in the coated fruit.

Figure 8 - Average values, regression equation and coefficient of determination of titratable acidity (% malic acid) of 'Prata' bananas, with and without coating of residual starch, glycerol and acetic acid, and stored (23.5±0.5 ºC and 73.3±2.4% RH), for 8 days.

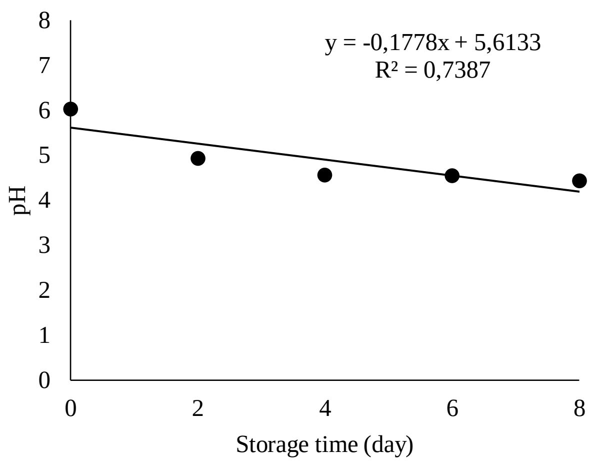


Means followed by the same letter, within each time, do not differ statistically from each other, using the Turkey test, to 5%.

Costa *et al.* (2019) found a similar behavior in control 'Prata Anã' bananas compared to those coated with starch solutions (2%, 5%, and 8%) during storage at 25±3°C for 12 days. The authors reported that increasing the starch solution concentration led to a longer time to reach the highest percentage of malic acid.

There was no significant interaction between control and coated bananas for pH, with differences observed only for storage time (Figure 9).

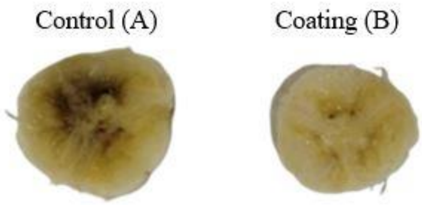
Figure 9 - Average values, regression equation and coefficient of determination of pH of 'Prata' bananas stored (23.5±0.5 ºC and 73.3±2.4% RH), for 8 days.



The decrease in pH during ripening is expected and is usually associated with the increasing acidity trend in fruit across all treatments (Oliveira *et al.*, 2018). Sousa, Feitosa, and Figueiredo (2018) also observed pH decreases in ‘Prata’ bananas stored at room temperature during storage, corroborating the acidity results, as these physicochemical parameters show inverse behaviors.

A difference in ripening was observed at the end of the storage period. The pulp of the uncoated (control) banana showed a significant visual difference, with darkened color in the center of the pulp and a more yellow hue toward the edges, characteristics associated with overripe. While the coated fruit showed no pulp darkening (Figure 10). Therefore, the coating was effective in delaying banana ripening.

Figure 10 - Comparison between banana pulp, control (A) and with a coating (B) from residual starch, glycerol and acetic acid at the end of the storage (8 days).



CONCLUSION

It was concluded that the coating of starch, acetic acid and glycerol applied to the banana peels delayed ripening during 8 days of storage (23.5±0.5ºC and 73.3±2.4% RH), highlighting the potential of using residual starch in postharvest conservation of fruits.

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