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Post-harvest conservation of banana 'Prata Gorutuba' using giberelic acid

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Abstract

Gibberellic acid is a plant growth regulator, naturally occurring in the plant, and is indicated to prolong the post-harvest life of bananas, increasing the storage and commercialization period. Therefore, the objective of the present work was to evaluate the conservation period of 'Prata-Gorutuba' bananas with different concentrations of gibberellic acid associated with refrigerated storage and modified atmosphere. 'Prata-Gorutuba' banana fruits were used to set up two independent experiments. In the first, the fruits were stored for 25 days in a cold room (14.5 ± 1 °C and relative humidity of 85 ± 5%) and the evaluations were carried out five days apart. In the second experiment, the fruits were removed from the cold chamber and packaging after 25 days of storage and kept in ambient conditions (25± 1 °C) for complete ripening and evaluations were carried out daily for five days. The experimental design for the two experiments was the DIC, with the first experiment in a 5x6 factorial scheme (concentrations x evaluation periods) and in the second experiment in a 5x5 factorial scheme (concentrations x evaluation periods), with four replications and four fruits per repetition. In the first experiment, concentrations of 500 and 1000 ppm of gibberellic acid were efficient in keeping the fruits stored for 25 days, at refrigerated temperatures and a modified atmosphere, positively influencing the color, pH and acidity characteristics. In the second experiment, gibberellic acid was efficient in delaying the color development of fruits stored for 29 days.

Keywords: modified atmosphere, *Musa spp.*, quality, storage

Introduction

The banana crop (Musa spp.) holds great social, economic, and nutritional importance. Brazil benefits from favorable edaphoclimatic conditions that allow the production of a wide variety of fruits. The northern region of the state of Minas Gerais stands out for producing mainly the cultivar 'Prata-Anã' (Queiroz et al., 2019), especially its clone known as 'Prata-Anã Gorutuba', which originated from a spontaneous mutation of the 'Prata-Anã' banana (Fernandes et al., 2019).

Fruits, in general, undergo significant losses from harvest to the moment they reach the final consumer. The ripening process involves substantial changes in physiological, biochemical, and sensory properties, such as increased respiration, ethylene production, pigment biosynthesis (carotenoids and anthocyanins), and softening of the texture to an acceptable quality level (Ntsoane et al., 2019). Among the factors that hinder the expansion of banana exports are those related to their high perishability, which compromises the competitiveness of the Brazilian product abroad.

The use of the cold chain is a common strategy to preserve banana quality during storage and transportation. However, temperatures below 13°C may cause physiological disorders, such as peel browning and impaired ripening, which affect not only domestic marketing but also export potential and competitiveness in the international market. Finding a balance in storage temperatures, combined with other techniques such as specific packaging and humidity control, is essential to minimize these effects and maintain banana quality throughout the supply chain (Aquino, 2016).

In addition to refrigeration, another alternative to extend postharvest shelf life is the use of plant growth regulators, particularly gibberellins. Gibberellic acid is a naturally occurring plant growth regulator and is

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recommended to prolong the postharvest life of bananas, increasing their storage and marketing period. Gibberellic acid (GA_3) can be applied to reduce the rate of fruit color change from green to yellow, inhibit the action of chlorophyllases, and suppress ethylene production. Furthermore, GA_3 delays pulp softening and carotenoid accumulation, thereby avoiding excessive postharvest losses during commercialization (Aquino, 2016). Within this context, the objective of this study was to evaluate different concentrations of gibberellic acid (GA_3) in the postharvest preservation of ‘Prata Gorutuba’ bananas stored under refrigeration and modified atmosphere.

Materials and Methods

The study was carried out at the Postharvest Physiology Laboratory of the State University of Montes Claros (UNIMONTES), Department of Agricultural Sciences, located at the Janaúba Campus, Minas Gerais, Brazil.

The fruits were obtained from a commercial plantation in the municipality of Mocambinho. The farm is located in the far north of Minas Gerais State, at 44° 01’ W longitude and 15° 05’ S latitude, with an altitude of 449 m. The bunches were harvested sixteen weeks after emergence, fourteen weeks after flower bud removal, at ripening stage 2. The hands were placed in plastic crates lined and covered with newspaper and transported to the laboratory. Afterwards, fruit selection was performed, discarding those damaged or showing symptoms of mechanical injury. The hands were divided into clusters of four fruits, which were then immersed for five minutes in a 1% neutral detergent solution to coagulate the latex, followed by rinsing in running water. Subsequently, the clusters were immersed for five minutes in a fungicide solution containing Magnate at a dosage of 200 mL 100 L^{-1} and Iharaguen-s at a dosage of 10 mL 100 L^{-1}. After drying, the fruits were distributed to compose the treatments.

To extend postharvest shelf life, thereby increasing the storage and marketing period, gibberellic acid (a plant growth regulator) was used. The fruits were immersed for three minutes in solutions with five different concentrations:

* 0 ppm de gibberellic acid (controle);
*500 ppm of gibberellic acid (1.25 g L^{-1} of Progibb 400);
*1000 ppm of gibberellic acid (2.5 g L^{-1} of Progibb 400);
*1500 ppm of gibberellic acid (3.75 g L^{-1} of Progibb 400);
*2000 ppm of gibberellic acid (5 g L^{-1} of Progibb 400).

For fruit storage, 16 µm low-density polyethylene (LDPE) packaging was used. The air inside was removed with a vacuum cleaner, and the packages were then sealed to prevent air entry. Subsequently, they were labeled, placed in standard cardboard boxes used for fruit export, and stored in a cold chamber at 14.5 ± 1 °C and 85 ± 5% relative humidity for 25 days, which corresponds to the period required for long-distance transport, such as shipping to the European market.

Two independent experiments were conducted. In the first experiment, fruits were stored for 25 days, and evaluations were carried out at five-day intervals. In the second experiment, fruits were stored for 25 days in a sealed cold chamber. After this period, the fruits were removed from the packaging and maintained at ambient conditions (25 ± 1 °C) for complete ripening, with daily evaluations performed over five days, representing the commercialization period.

The experimental design for both experiments was completely randomized (CRD). In the first experiment, a 5 × 6 factorial scheme (concentrations × evaluation periods) was used, and in the second experiment, a 5 × 5 factorial scheme (concentrations × evaluation periods), with four replications and four fruits per replication.

Fruits were evaluated for firmness using a Brookfield CT3 10 KG digital texture analyzer. Measurements were performed at the median region of the fruit and determined by the penetration force required for a 4 mm diameter probe to penetrate 8 mm into the pulp. Results were expressed in Newtons (N). Peel color was measured using a Color Flex 45/0 (2200) colorimeter, stdzMode:45/0, with direct reflectance readings of the L* (lightness), a* (red–green coordinate), and b* (yellow–blue coordinate) values, processed through the HunterLab Universal Software. From the L*, a*, and b* values, the hue angle (°h*) and chroma index (C*) were calculated.

To determine fresh mass loss, fruits from each treatment replication were weighed using an electronic scale with 0.1 g precision. The difference in weight between evaluations was accumulated throughout the experiment, considering the difference between the initial fruit mass and that recorded at each sampling period. Results were expressed as a percentage.

For chemical analyses, composite samples of four homogenized fruits were used. Soluble solids content was determined by refractometry using an ATAGO bench refractometer, model N-1 a, with a reading range of 0 to 95 °Brix, and results were expressed in °Brix. Titratable acidity was determined by titrimetry, using 10 g of pulp diluted in 90 mL of distilled water, followed by titration with standardized 0.1 M NaOH solution, using phenolphthalein as the indicator. Results were expressed in milligrams of malic acid per 100 g of sample. The pH was measured with a bench pH meter equipped with a glass membrane electrode, calibrated with buffer solutions at pH 4.0 and 7.0. Determinations were performed directly by potentiometry, consisting of immersing the pH electrode in the homogenized sample.

The data obtained for the evaluated traits were subjected to analysis of variance (ANOVA) using the statistical software Sisvar. When the F-test was significant, means were fitted to regression models.

Results and Discussion

Experiment 1

The variable fresh mass loss showed a significant effect only for the storage period ($p < 0.05$), with the curve exhibiting a linear adjustment. Fresh mass loss increased throughout storage (**Figure 1**). On the 25th day of storage, the fruits recorded a fresh mass loss of 1.5%, which is below the 5% threshold and, in practical terms, did not affect the final quality of the fruits after 25 days of storage. Aquino et al. (2016), studying the effect of gibberellic acid on the preservation of 'Maçã' bananas, also observed a linear increase in fruit mass loss during storage. Fruit mass loss is a consequence of high transpiration and respiration rates, which lead to water loss from the fruits to the environment (Oliveira et al., 2017).

Fruit firmness showed a significant effect only for the storage period ($p < 0.05$), with the curve exhibiting a quadratic adjustment. During storage, firmness values first increased and then decreased: the initial mean value was 40.27 N, on the 15th day of storage it reached 41 N, and by the 25th day it had decreased to 36.3 N (**Figure 2**). The reduction in firmness, also known as fruit softening, results from cell wall degradation due to increased enzymatic activity, associated with other processes such as starch hydrolysis and water loss, ultimately contributing to fruit softening (Chitarra & Chitarra, 2005). Fruit firmness is one of the main quality attributes, as it affects resistance during transport, shelf life, and market price. Moreover, it is a primary factor considered by consumers when purchasing fruit (Chen et al., 2019).

Lightness, represented by the L* coordinate, showed no significant difference for any of the factors tested ($p > 0.05$). **Figure 3** presents the chromaticity values, which express color intensity. This variable showed a significant effect only for the storage period and fitted the quadratic model. On the first day of storage, the fruits exhibited a color intensity of 36.81, which decreased to 35.37 on the 15th day; from that point onward, a marked increase was observed. The chromaticity value on the 25th day was 38.01. Higher chromaticity values in the first days after harvest may be due to the heterogeneity of fruit ripening stage at the time of harvest (Morais et al.,2003).

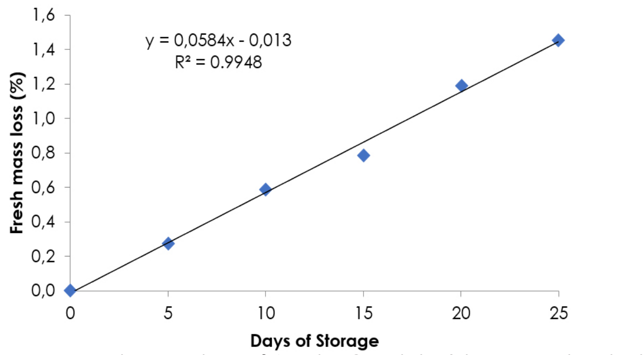


Figure 1. Fresh mass loss of 'Prata Gorutuba' bananas treated with different concentrations of gibberellic acid and stored at 14.5 ± 1 °C and 85 ± 5% relative humidity, in Janaúba, MG.

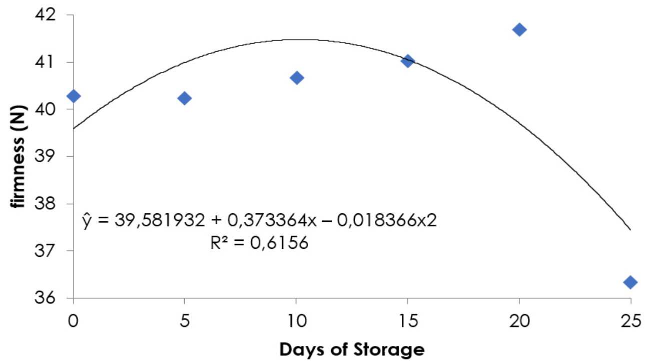


Figure 2. Firmness of 'Prata Gorutuba' bananas treated with different concentrations of gibberellic acid and stored at 14.5 ± 1 °C and RH of 85 ± 5%, in Janaúba – MG.

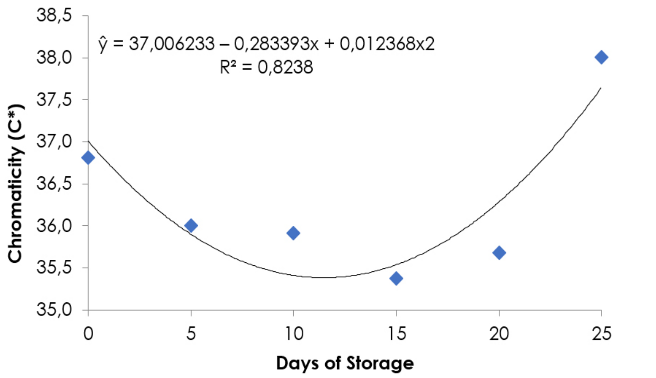


Figure 3. Chromaticity (C*) of 'Prata Gorutuba' bananas treated with different concentrations of gibberellic acid and stored at 14.5 ± 1 °C and 85 ± 5% relative humidity, in Janaúba, MG.

Peel color, represented by the hue angle, showed a significant interaction between storage period and gibberellic acid concentrations ($p < 0.05$). The hue angle, which indicates the progression of banana peel color from green to yellow, presented values of 89.85, 104.09, 103.76, 97.08, and 100.23 for the concentrations of 0, 500, 1000, 1500, and 2000 ppm, respectively, on the 25th day of storage (**Figure 4**). This indicates that fruits treated with gibberellic acid at concentrations of 500 and 1000 ppm maintained a green coloration closer to that observed at harvest (hue = 102.35). It was observed that at concentrations of 0, 1500, and 2000 ppm, there was a reduction in hue angle on the 25th day of storage. This change indicates the progression of banana peel color from green to yellow.

The color changes occurring during fruit ripening are associated with degradative and/or synthetic processes of pigments present in the fruit (Chitarra & Chitarra, 2005). In bananas, during ripening, chlorophyll degradation (green color) is intense, making the preexistence of carotenoid pigments (yellow to orange color) visible, while the synthesis of other pigments occurs at relatively low levels (Silva et al., 2006).

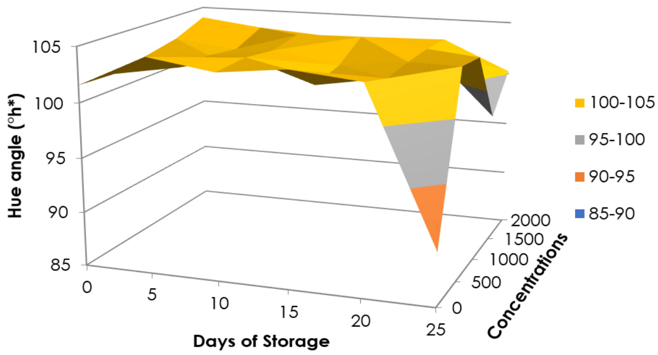
Soluble solids content showed a significant effect only for the storage period ($p < 0.05$), with the curve adjusted to a quadratic model. On the first day of storage, the fruits had an average content of 3.94 °Brix, reaching 8.42 °Brix on the 25th day (**Figure 5).**

Castro et al. (2012) also observed that in Tommy Atkins mango fruits treated with gibberellic acid in preharvest, there was a trend of increasing soluble solids content during storage. This increase is considered normal in so-called climacteric fruits, due to changes in structural carbohydrates such as hemicelluloses and pectin, as well as the conversion of organic acids (Mustapha et al., 2020). The conversion of starch into simple sugars is one of the main reasons for the increase in soluble solids content during banana ripening (Cordeiro et al., 2014).

The pH variable showed a significant interaction ($p < 0.05$) between storage period and gibberellic acid concentrations. During storage, there was an increase in pH followed by a subsequent decrease in all treatments (**Figure 6**). The initial mean pH value was 5.7; on the 5th and 10th days, there was a slight increase, reaching a mean value of 5.9, and by the 25th day this value had decreased to 5.3. This variation was possibly due to the non-uniformity of the fruits from the field. It was observed that the concentrations of 500 and 1000 ppm showed higher pH values during storage.

Lima (2003), working with gibberellic acid at concentrations of 100 mg L^{-1} and 200 mg L^{-1} for postharvest preservation of guava, observed that pH values increased with storage time. Carvalho et al. (1998), studying the effect of gibberellic acid on the preservation of 'Fuyu' persimmon, observed a slight decrease in pH during the first two weeks of storage and a slow increase during the final stages of ripening.

Titratable acidity showed a significant interaction between storage period and gibberellic acid concentrations ($p < 0.05$). An increase in acidity values



Day 0 $\hat{Y}$ = 102,34770
Day 5 $\hat{Y}$ =102,90415
Day 10 $\hat{Y}$ =103,40969
Day 15 $\hat{Y}$ =102,94009
Day 20 $\hat{Y}$ =103,06080
Day 25 $\hat{Y}$ =99,00303

0 ppm $\hat{Y}$= 100,672225 + 1,109682x – 0,058274x^2
500 ppm $\hat{Y}$ =102,65788
1000 ppm $\hat{Y}$ =102,80139
1500 ppm $\hat{Y}$ =102,09792
2000 ppm $\hat{Y}$ =102,64184

Figure 4. Hue angle (°h*) of 'Prata Gorutuba' bananas treated with different concentrations of gibberellic acid and stored at 14.5 ± 1 °C and 85 ± 5% relative humidity, in Janaúba, MG.

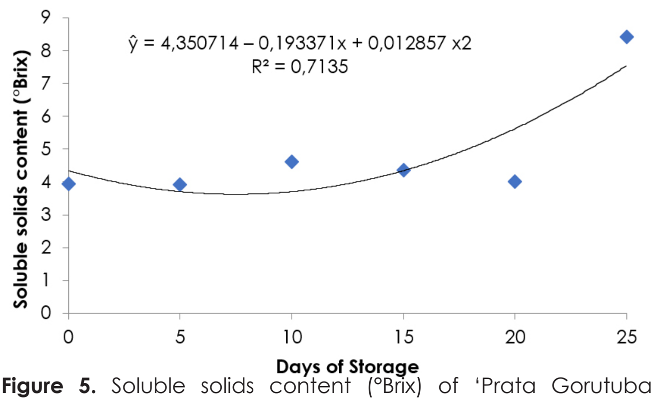
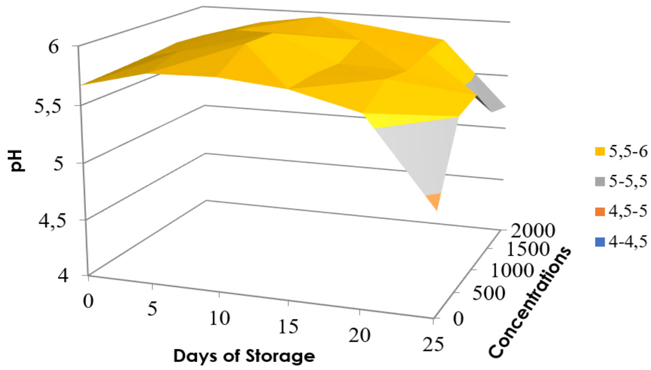


Figure 5. Soluble solids content (°Brix) of 'Prata Gorutuba' bananas treated with different concentrations of gibberellic acid and stored at 14.5 ± 1 °C and 85 ± 5% relative humidity, in Janaúba, MG.



Day 0 $\hat{Y}$ =5,70350
Day 5 $\hat{Y}$ =5,86200
Day 10 $\hat{Y}$=5,852357 + 0,000204x
Day 15 $\hat{Y}$ =5,80800
Day 20 $\hat{Y}$=5,662 + 0,000077x
Day 25 $\hat{Y}$ =5,28650

0 ppm $\hat{Y}$= 5,623571 + 0,062829x – 0,003557x^2
500 ppm $\hat{Y}$= 5,711339 + 0,041098x – 0,001984x^2
1000 ppm $\hat{Y}$= 5,727054 + 0,031777x – 0,001577x^2
1500ppm $\hat{Y}$= 5,715357 + 0,048786x – 0,002557x^2
2000 ppm $\hat{Y}$= 5,678128 + 0,063355x – 0,003184x^2

Figure 6. pH values of 'Prata Gorutuba' bananas treated with different concentrations of gibberellic acid and stored at 14.5 ± 1 °C and 85 ± 5% relative humidity, in Janaúba, MG.

was observed for all concentrations during storage (**Figure 7**). On the first day of storage, the fruits presented a mean acidity of 0.205 mg malic acid 100 mL^{-1} of juice, which increased to 0.336 mg malic acid 100 mL^{-1} of juice by the 25th day of storage. The control treatment showed higher acidity values compared to the treatments with gibberellic acid, possibly because the fruits in this treatment were at a more advanced ripening stage than the others. At the 25th day of storage, the concentrations of 0, 500, 1000, 1500, and 2000 ppm of gibberellic acid reached values of 0.605, 0.260, 0.260, 0.260, and 0.297 mg malic acid 100 mL^{-1} of juice, respectively.

Similar values of titratable acidity were reported by Castro et al. (2012) in Tommy Atkins mango fruits treated with gibberellic acid in preharvest. According to Chitarra & Chitarra (2005), acidity can be used as a reference point for the ripening stage of fruits, being mainly attributed to organic acids dissolved in the vacuoles of the cells. The level of titratable acidity is intrinsically related to pulp quality and preservation status, influencing characteristics such as flavor, aroma, color, and stability. Moreover, it can serve as an indicator of food deterioration (Oliveira et al., 2018).

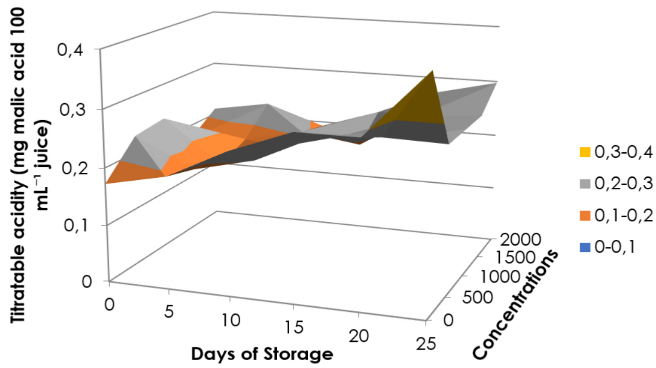
Organic acids are used in respiration for ATP production, resulting in a decrease in fruit acidity. However, the respiratory process itself also produces organic acids that may accumulate in the fruit, leading to a slight increase (Pimentel et al., 2010). In the present study, an increase in acidity was observed, probably because the production of organic acids was greater than their consumption during the respiratory process.

Experiment 2

Firmness was significant only for the storage period ($p < 0.05$), with the curve fitting a quadratic model. A reduction in firmness values was observed during storage (**Figure 8**). When removed from cold storage (25th day of storage), the fruits presented an average firmness of 43.083 N, and by the 29th day of storage, firmness had decreased to 6.227 N.

Blum et al. (2011), working with 'Kyoto' persimmons treated with gibberellic acid in preharvest, observed that GA_3 application maintained higher firmness, providing favorable results. According to Chitarra & Chitarra (2005), the application of gibberellins can partially inhibit ethylene action, affecting softening and peel color, delaying chlorophyll degradation and carotenoid accumulation.

The L* coordinate, which represents lightness, showed a significant effect only for the storage period ($p < 0.05$) and fitted the quadratic model. A reduction followed by an increase in lightness values was observed, decreasing from 62.74 on the 25th day of storage to 60.89 on the 27th day, and reaching 66.496 on the 29th day (**Figure 9**).



Day 0 $\hat{Y}$= 0,184571 + 0,00007x
Day 5 $\hat{Y}$= 0,1985 – 0,000077x
Day 10 $\hat{Y}$ =0,2105
Day 15 $\hat{Y}$= 0,292857 – 0,000108x
Day 20 $\hat{Y}$= 0,288 – 0,000068x
Day 25 $\hat{Y}$= 0,568786 – 0,000560x

0 ppm $\hat{Y}$= 0,197321 – 0,008418x
500 ppm $\hat{Y}$=0,200119 + 0,002557x
1000 ppm $\hat{Y}$= 0,215536 – 0,003861x + 0,000246x^2
1500 ppm $\hat{Y}$= 0,176071 + 0,000686x + 0,000114x^2
2000 ppm $\hat{Y}$= 0,194524 + 0,003471x

Figure 7. Titratable acidity (mg malic acid 100 mL^{-1} juice) of 'Prata Gorutuba' bananas treated with different concentrations of gibberellic acid and stored at 14.5 ± 1 °C and 85 ± 5% relative humidity, in Janaúba, MG.

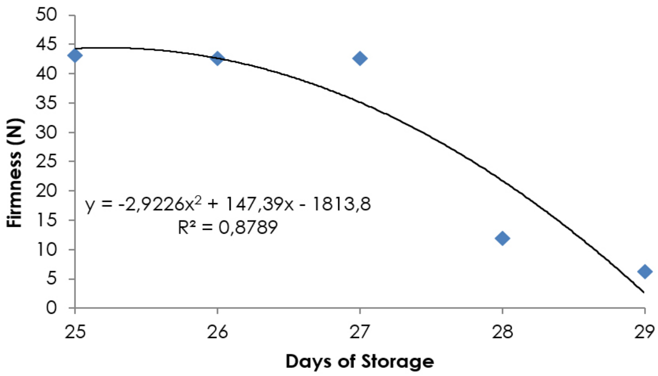


Figure 8. Firmness (N) of 'Prata Gorutuba' bananas treated with different concentrations of gibberellic acid and stored at 25 ± 1 °C, in Janaúba, MG.

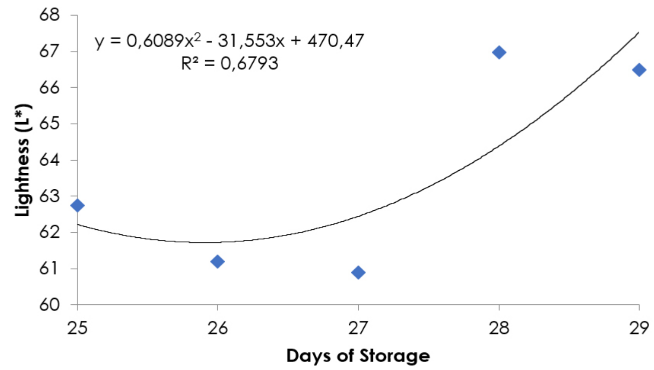


Figure 9. Lightness (L*) of 'Prata Gorutuba' bananas treated with different concentrations of gibberellic acid and stored at 25 ± 1 °C, in Janaúba, MG

During the ripening process, fruits undergo an intensification of their color. As observed by Barbosa (2019), during banana ripening, lightness values tend to increase due to changes in peel color, which shifts from green (lower values) to yellow (higher values). Color plays a crucial role in food quality evaluation, as visual perception is the first sense to be activated, playing a decisive role in product choice and acceptance.

The chromaticity variable showed a significant interaction between storage period and gibberellic acid concentrations ($p < 0.05$). An increase in chroma values was observed for all gibberellic acid concentrations during storage (**Figure 10**). Mean chroma values increased from 36.43, 38.03, 36.24, 36.01, and 36.38 on the 25th day to 43.50, 42.02, 41.63, 42.50, and 41.46 on the 29th day of storage for the doses of 0, 500, 1000, 1500, and 2000 ppm, respectively. It was observed that the doses of 1000 and 2000 ppm GA_3 presented the lowest chromaticity values, indicating that these fruits remained in better preservation status compared to the control fruits.

Chromaticity indicates color intensity, representing saturation in relation to the pigments present. In bananas, during ripening, chlorophyll degradation (green color) is intense, revealing the preexistence of carotenoid pigments (yellow to orange color), while the synthesis of other pigments occurs at relatively low levels (Barbosa et al., 2019).

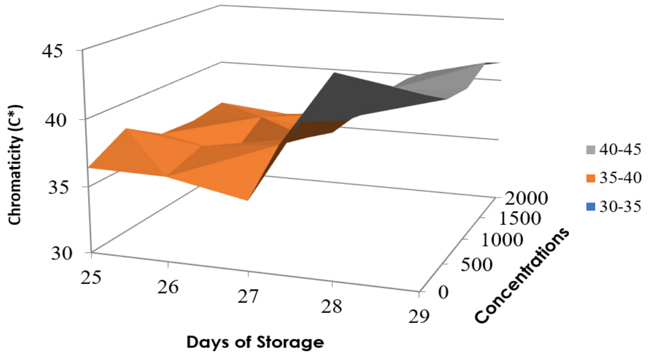
The hue angle, which indicates the progression of banana peel color from green to yellow, showed a significant interaction ($p < 0.05$) between storage period and gibberellic acid concentrations. It was observed that at 25, 26, and 27 days of storage, hue angle values remained similar across all gibberellic acid concentrations, and from the 28th day onward, a reduction was observed (**Figure 11**). Gibberellic acid was effective in delaying color development, since the control treatment showed lower mean hue angle values at the end of the experiment (82.94°) compared to the fruits treated with gibberellic acid.

The application of gibberellins delays the disappearance of the green color in bananas and, in some cases, slightly postpones the climacteric respiration peak (Chitarra & Chitarra, 2005).

According to Cordeiro (2013), during ripening, as peel color changes from green to yellow, there is a reduction in peel hue angle values, in agreement with the hue angle behavior observed in the present study.

The loss of green color is due to the structural decomposition of chlorophyll, resulting from several factors acting either individually or in combination. Among these factors are changes in pH, mainly caused by the accumulation of organic acids and other compounds in the vacuoles; the activation of the chlorophyllase enzyme; and the presence of oxidizing systems (Chitarra & Chitarra, 2005).

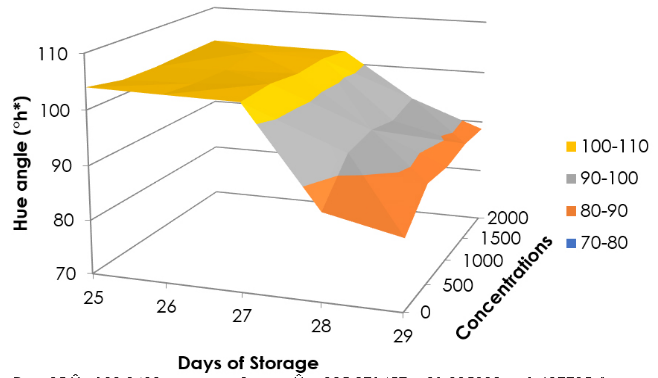
The soluble solids variable showed a significant effect only for the storage period ($p < 0.05$) and fitted



Day 25 $\hat{Y}$ =36,62045
Day 26 $\hat{Y}$ =36,24549
Day 27 $\hat{Y}$= 35,660696 + 0,002723x -0,0000001x^2
Day 28 $\hat{Y}$ =41,44359
Day 29 $\hat{Y}$ =42,2261

0 ppm $\hat{Y}$= 427,442133 – 31,090941x + 0,617257x^2
500 ppm $\hat{Y}$= 373,278595 – 25,95767x + 0,501575x^2
1000 ppm $\hat{Y}$= -6,813105 + 1,66685x
1500 ppm $\hat{Y}$= 377,693894 – 26,911145x + 0,529884x^2
2000 ppm $\hat{Y}$= 357,346266 – 25,190961x + 0,493664x^2

Figure 10. Chroma (C*) of 'Prata Gorutuba' bananas treated with different concentrations of gibberellic acid and stored at 25 ± 1 °C, in Janaúba, MG.



Day 25 $\hat{Y}$ =103,0408
Day 26 $\hat{Y}$ =103,2541
Day 27 $\hat{Y}$ =103,3102
Day 28 $\hat{Y}$= 86,763641 + 0,010365x -0,000004x^2
Day 29 $\hat{Y}$ =87,35801

0 ppm $\hat{Y}$= -925,271457 + 81,895032x – 1,627705x^2
500 ppm $\hat{Y}$= -901,744204 + 78,16777x – 1,519323x^2
1000 ppm $\hat{Y}$= -925,631068 + 79,906176x – 1,551057 x^2
1500 ppm $\hat{Y}$= - 811,163868 + 71,535586x – 1,398132x^2
2000 ppm $\hat{Y}$= -746,601880 + 66,563755x – 1,303x^2

Figure 11. Hue angle (°h*) of 'Prata Gorutuba' bananas treated with different concentrations of gibberellic acid and stored at 25 ± 1 °C, in Janaúba, MG.

the quadratic model. A significant increase in soluble solids content was observed, from 5.48 °Brix on the 25th day to 27.11 °Brix on the 29th day of storage **(Figure 12)**. The increase in soluble solids content is probably due to fruit ripening. Soluble solids content increased as fruit color indices indicated a more advanced ripening stage, which, according to the hue angle, changed from green (25th day) to yellow (29th day). Bananas are fruits with a high starch content when green, and as they ripen, starch is broken down into sugars to be used in respiration, thereby increasing soluble solids content.

Soluble solids indicate the amount of solids dissolved in the pulp and, during ripening, their content tends to increase due to the biosynthesis of soluble sugars or the degradation of polysaccharides (Chitarra & Chitarra, 2005).

pH showed a significant interaction (p <

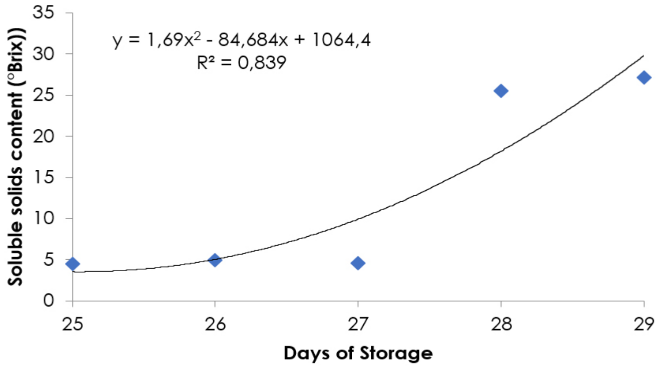


Figure 12. Soluble solids content (°Brix) of 'Prata Gorutuba' bananas treated with different concentrations of gibberellic acid and stored at 25 ± 1 °C, in Janaúba, MG.

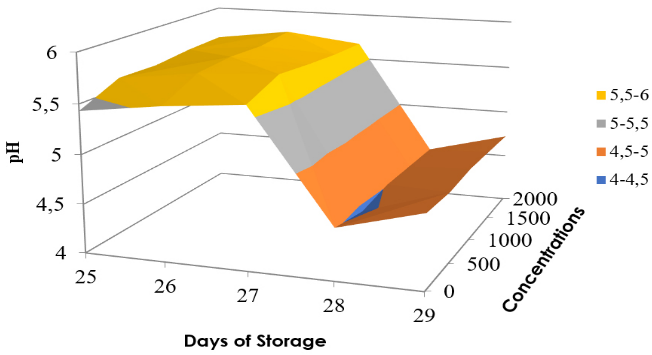
0.05) between storage period and gibberellic acid concentrations. When removed from cold storage (25 days), the fruits presented a mean pH of 5.58, which remained similar on the 26th and 27th days with values of 5.69 and 5.68, respectively. On the 28th day, pH decreased in all treatments, presenting mean values of 4.49, and on the 29th day it increased again, reaching a mean value of 4.73 (**Figure 13**). Similar results were found by Carvalho et al. (1998), who, working with gibberellic acid in the preservation of 'Fuyu' persimmon, observed a decrease followed by an increase in pH values.

Titratable acidity showed a significant effect only for the storage period ($p < 0.05$) and fitted the linear model. An increase in acidity values was observed up to the 28th day, reaching 0.606 mg malic acid 100 mL⁻¹ juice, and on the 29th day of storage there was a slight reduction in malic acid content (**Figure 14**).

Silva (2018), working with gibberellic acid in the preservation of 'Itália' grapes, also observed an increase followed by a reduction in titratable acidity values. According to Chitarra & Chitarra (2005), as ripening progresses, a reduction in titratable acidity occurs as a consequence of the decline in the respiratory process.

Conclusions

In the first experiment, the concentrations of 500 and 1000 ppm of gibberellic acid, combined with refrigeration and modified atmosphere, were effective in maintaining 'Prata Gorutuba' bananas stored for 25 days, preserving a greener coloration for a longer period, higher pH values (closer to those found in greener bananas), and consequently lower acidity. The second experiment demonstrated that the use of gibberellic acid was effective in delaying the color development of 'Prata Gorutuba' bananas stored for 29 days. This effect had a positive impact both on the market and on shelf life, by extending fruit longevity and providing better control over ripening. As a result, losses could be reduced and demand increased, due to the greater freshness and durability of the bananas.



Day 25 $\hat{Y}$= 5,451929 + 0,000251x
Day 26 $\hat{Y}$= 5,556143 + 0,000266x
Day 27 $\hat{Y}$= 5,632143 + 0,000172x
Day 28 $\hat{Y}$= 4,4975
Day 29 $\hat{Y}$ =4,735

0 ppm $\hat{Y}$= - 36,275357 + 3,318964x -0,065893 x^2
500 ppm $\hat{Y}$= -38,243429 + 3,534857x – 0,071071 x^2
1000 ppm $\hat{Y}$= - 36,542357 + 3,399964x – 0,068393x^2
1500 ppm $\hat{Y}$= -30,071429 + 2,928107x – 0,059821x^2
2000 ppm $\hat{Y}$= -30,424286 + 2,965571x – 0,060714x^2

Figure 13. pH values of 'Prata Gorutuba' bananas treated with different concentrations of gibberellic acid and stored at 25 ± 1 °C, in Janaúba, MG.

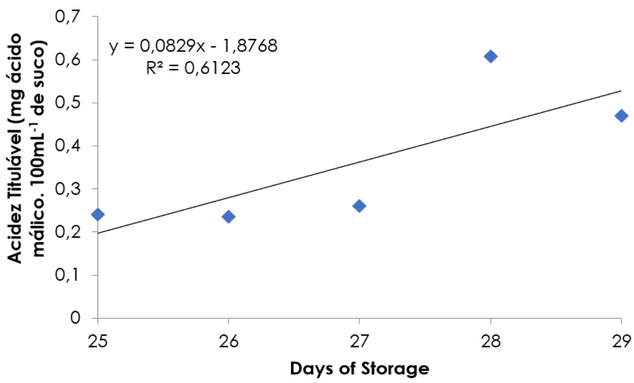


Figure 14. Titratable acidity (mg malic acid 100 mL□¹ juice) of 'Prata Gorutuba' bananas treated with different concentrations of gibberellic acid and stored at 25 ± 1 °C, in Janaúba, MG.

References

Aquino, C.F., Salomão, L.C.C., Azevedo, A.M. 2016. Qualidade pós-colheita de banana 'Maçã' tratada com ácido giberélico avaliada por redes neurais artificiais. *Pesquisa agropecuária brasileira* 51: 824-833.

Barbosa, L.F.S., Alves, A.L., Sousa, K.S.M., Neto, A.F., Cavalcante, I.H.L., Vieira, J.F. 2019. Qualidade pós-colheita de banana 'pacovan' sob diferentes condições de armazenamento. *Magistra* 30: 28 – 36.

Blum, J., Ayub, R., Malgarim, M. 2011. Época de colheita e qualidade pós-colheita do caqui cv. Fuyu com a aplicação pré-colheita de ácido giberélico e aminoetoxivinilglicina. Biotemas. 21.

Castro, J.C., Marsolla, D.A. , Kohatsu, D.S. , Rerison, C.H. , Scanavacca, J., Feniman, C. M. 2012. Armazenamento e qualidade de frutos da mangueira (*Mangifera indica* L.) tratados com ácido giberélico. *Journal of Agronomic Sciences* 1: 76-83.

Carvalho, A.V. *et al*. 1998. Emprego de ácido giberélico (GA_3) na conservação de caqui (Diospyros koki L.) cv. Fuyu, armazenados em atmosfera modificada sob refrigeração. *Revista Universidade Alfenas* 4: 121-126.

Chen, G., Dong, S., Zhao, S., Li, S., Chen, Y. 2019. Improving functional properties of zein film via compositing with chitosan and cold plasma treatment. *Industrial Crops and Products* 129: 318-326.

Chitarra, M.I.F., Chitarra, A.B. 2005. *Pós-colheita de frutas e hortaliças: fisiologia e manuseio*. UFLA, Lavras, Brasil. 785 p.

Cordeiro, M, Mizobutsi, G., Silva, N., Oliveira, M., Sobral, R., Mota, W.. (2014). Conservação pós-colheita de manga var. Palmer com uso de 1-metilciclopropeno. *Magistra* 26: 103- 114.

Lima, M. A. *Conservação pós-colheita de goiaba pelo uso de reguladores de crescimento vegetal, cálcio e da associação destes com refrigeração e embalagens plásticas.* 2003. Tese (Doutorado em Produção Vegetal) – Universidade Estadual Paulista, Jaboticabal, Brasil.

Morais, P.L.D., Filgueiras, H.A., Pinho, J.L.N., Elesbão, R.A., Assis, J. 2003. Vida útil de mangos cv. Tommy Atkins recolectados em el estádio de maduración comercial. *Revista Iberoamericana de Tecnologia Postcosecha* 5: 26-32.

Mustapha, A.T., Zhou, C., Wahia, H., Amanor-Atiemoh, R., Otu, P., Qudus, A., Fakayode, O.A., Ma, H. 2020. Sonozonation: Enhancing the antimicrobial efficiency of aqueous ozone washing techniques on cherry tomato. *Ultrasonics Sonochemistry* 64: 1-12.

Ntsoane, Lucia & Zude-Sasse, M. & Mahajan, Pramod & Sivakumar, Dharini. (2019). Quality assesment and postharvest technology of mango: A review of its current status and future perspectives. Scientia Horticulturae. 249. 77-85.

Oliveira, Luana & Rodrigue, Marília & Bomfim, Marinês & Sousa, Valéria & Trigueiro, Rodolfo & Melo, Esthefani. (2017). Uso de coberturas comestíveis a base de fécula de mandioca associado à refrigeração na qualidade pós-colheita de goiaba paluma. Revista Verde de Agroecologia e Desenvolvimento Sustentável. 12. 540.

Oliveira, E.N.A.; Feitosa, B.F.; Souza, R.L.A. 2018. *Tecnologia e processamento de frutas: doces, geleias e compotas*. IFRN, Natal, Brasil. 315 p.

Pimentel, R.M.A., Guimarães, F.N., Santos, V.M., Resende, J.C.F.2010. Qualidade pós-colheita dos genótipos de banana PA42-44 e Prata-anã cultivados no norte de Minas Gerais. *Revista Brasileira de Fruticultura* 32: 407-413.

Queiroz, L.G.C., Jesus, M.O., Aguiar, F.S., Paraizo, E.A., Soares, M.C., Pinheiro, J.M.S., Mizobutsi, G.P., Rodrigues, M.L.M., Santos, T.C. 2019. Influence of Different 'Prata-Anã' Banana Bunch Ages on Post-Harvest Quality. *Journal of Experimental Agriculture International*, Hooghly, v.36: 1-14.

Rodrigues, F.E. *Ficha Técnica Prata Gorutuba (Musa AAB 'Prata anã' clone: Gorutuba)*. 2009. Disponível em:<http://www.sbwbrasil.com.br/pdf/Ficha-tecnica-Prata-Gorutuba.pdf>.Acesso em: 08 de Março de 2016.

Silva, C.S., Lima, L.C., Santos, H.S., Camili, E.C., Vieira, C.R.Y.I., Martin, C.S., Vieites, R.L. 2006. Amadurecimento de banana-prata climatizada em diferentes dias após a colheita. *Ciência e Agrotecnologia* 30: 103-111.

SILVA, J. L. S. *Reguladores vegetais na pós-colheita das uvas 'itália' do sistema de produção convencional e 'Niagara Rosada' do sistema orgânico.* 2018. 47f. (Trabalho de conclusão de curso) Universidade Federal do Pampa, Dom Pedrito, Rio Grande do Sul, Brasil.

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