Original research article

INFLUENCE OF DIFFERENT 'PRATA-ANÃ' BANANA BUNCH AGES ON POST-HARVEST QUALITY

ABSTRACT

Objective: To determine the ideal harvest season of 'Prata-Anã' banana bunches by means of physical and chemical analyses of fruit cultivation conditions in the northern state of Minas Gerais.

Study Design: The employed experimental design was the completely randomized design was used in a 5x5 factorial scheme, with five bunch ages and five assessment days.

Study Location and Duration: The experiment was run in an area with banana trees planted 20 months beforehand, located at Unimontes's Experimental Farm, at 530m of altitude, with coordinates being -15°43'46.99" south latitude and -43°19'17.61"west longitude, between April and November 2017.

Methodology: The bananas bunches the were marked weekly from April 14 to May 12, and week days were standardized for each marking. Five bunch ages were defined – 16, 17, 18, 19 and 20 weeks after inflorescence emission – for harvest. For differentiation of emerged bunches, tapes of different color were used. When the bunches marked in the first week completed 20 weeks, all bunches were harvested, which happened on September 1. After harvested the fruits were subjected to storage in refrigerated chamber at 10°C ± 1°C and relative humidity of 90% +5% for 25 days. After being stored for 25 days, the bananas were taken out of the chamber and exposed to a room temperature of 25oC, which analyzes were performed for 9 days, with a two-day interval in between, simulating the marketing period. The following analyses were carried out: firmness, peel color, soluble solids, pH, titratable acidity, amide, total sugars, reducing sugars and electrolyte extravasation.

Results: Lower hue, chroma, soluble solids, titratable acidity, total sugar, reducing sugar and electrolyte extravasation values were found for bananas harvested at 16 weeks.

Conclusion: Bunch harvest age had a direct influence on post-harvest quality of bananas 'Prata-Anã'. Fruits from 16-week bunches were superior in physical and chemical characteristics compared to other ages, meaning a longer post-harvest life.

Keywords: storage, *musa* ssp, maturation stage

1. INTRODUCTION

Banana trees (*Musa* spp.) are the most relevant fruitful trees worldwide and its production is mostly concentrated in tropical countries, being the second most produced fruit in Brazil [1]. According to [2], in 2016, Brazil was the third among countries with the highest banana production, behind India and China only; besides, this fruit appears among the three most produced tropical fruits, alongside orange and pineapple.

The southwest region is the second greatest banana producer, with the north of Minas Gerais being a major producing pole in Brazil, with a high social and economic importance for the region. Banana 'Prata-Anã' (AAB) and its different clones are the most prevalent in cultivation, with good market acceptance due to their excellent quality attributes, being considered elementary in nutrition.

For being climacteric fruits classified as perishable, bananas require techniques that slow down their rapid ripening, preventing post-harvest losses, especially while being transported to more distant consuming markets.

Harvesting fruits at proper maturation stages is determinant to maintaining post-harvest quality. Maturation point is the ideal harvest moment without the occurrence of damages, which provides fruits with a longer preservation period. This point is usually reached when the fruit becomes physiologically mature, which corresponds to its maximum size and weight, but does not have desirable characteristics for marketing and consumption. Later, the fruit continues to go through transformations, ripens naturally and becomes suitable for consumption. However, the ideal harvest point depends on correlations between physiological characteristics inherent of each variety, the ideal maturation stage, and post-harvest preservation technologies applied. In banana trees, fruits harvested prematurely may not be physiologically developed, which hinders their ripening process and final quality [3]. Nevertheless, harvesting overripe fruits leads to rapid quality loss, reducing theirmarketing period.

In addition to defining the best harvest stage, another way of reducing damages and prolonging storage period is to keep fruits refrigerated. Refrigeration is considered one of the most efficient methods for fruit preservation, maintaining the fruit's desirable characteristics, similar to those of its early stage, due to a delayed maturation process.

A fruit's external characteristics – which relate to its appearance as well as size, shape, color, lightness, absence of imperfections – and internal characteristics – perceived in how it tastes, smells and feels – are the main attributes evaluated by consumers, who demand for quality during purchase [3].

Therefore, determining the ideal harvest point of bunches is imperative, when the fruit reaches its physiological maturation, that is, its maximum size and weight, which will influence its post-harvest quality and resistance for a longer preservation period.

The present study aimed to determine the ideal harvest season of banana 'Prata-Anã' bunches by means of physical and chemical analyses on fruits maturing under cultivation conditions in the north of Minas Gerais, allowing for their maximum utilization in order to provide the final consumer with quality, in accordance with their demands and preferences.

2. MATERIAL AND METHODS

2.1 Fruit Material, Post-harvest Treatment and Environmental Conditions

The experiment was run in an area with banana trees planted 20 months beforehand, located at Unimontes's Experimental Farm, at 530m of altitude, with coordinates being -15°43'46.99" south latitude and -43°19'17.61"west longitude. After inflorescence emission, the banana trees were randomly selected and marked through criterion proposed by [4] for sourcing of bananas at different bunch ages. They were marked weekly from April 14 to May 12, and week days were standardized for each marking. Five bunch ages were defined – 16, 17, 18, 19 and 20 weeks after inflorescence emission – for harvest. For differentiation of emerged bunches, tapes of different color were used. When the bunches marked in the first week completed 20 weeks, all bunches were harvested, which happened on September 1. After harvest, the bunches were separated into bouquets with four fruits each and washed in water and neutral detergent at 0.2% for latex coagulation and superficial cleaning. The bouquets were then immersed in a solution of Imazalil fungicide, at a dose of $2mL.100mL^{-1}$ of water at room temperature, and dried outdoors. Each bouquet was stored in low-density polyethylene packs measuring 25µm in thickness and put inside a standard cardboard box for export. The fruits were subjected to storage in refrigerated chamber at 10°C ± 1°C and relative humidity of 90% ±5% for 25 days. After being stored for 25 days, the bananas were taken out of the chamber and packs and exposed to a room temperature of 25°C, after which they were analyzed for 9 days, with a two-day interval in between, simulating the marketing period.

2.2 Physical Quality Attributes

Peel and pulp firmness: determined by maximum penetration strength with a flat tip measuring 4 mm in diameter, placed 10mm away from the fruit, with the aid of a Brookfield digital penetrometer, model CT3 10 KG; measures were taken from the medium area of the four fruits of the bouquet with and without peel, and results were expressed as Newton (N).

Peel color: Reading was carried out on the four fruits of the bouquet, using the Color Flex digital colorimeter, model CT3 10 KG, which expresses color using three parameters: L*(lightness), which ranges from 0 (black) to 100 (white); a* (transition from green (-a*) to red (+a*)) and b* (transition from blue (-b*) to yellow (+b)). Based on L*, a* and b* values, hue angle (°h) and chroma saturation index (C*) were calculated.

The angle Hue (° h) represents a new coloration of fruits, which varies from 0 to 360 ° where 0 ° represents red color, 90 ° yellow color, 180 ° green color, 270 ° color blue and the 360 ° red color again.

- ° h * = actg (a * / b *) (-1) 90 for a * negative;
- ° h * = 90- (actg (a * / b *)) for a * positive

Chroma saturation index (C *) is a saturation risk of color pigments, consequently reducing color intensity, varying from 0 to 60°, where 0 are close to gray and 60° pure, calculated from the following formula:

- C * = √ (a *) 2 (b *) 2

2.3 Determination of Chemical Quality Parameters

Soluble solids: analysis performed by means of Reichert digital refractometer, using the four banana pulp kneaded in food processor, with results expressed as °Brix.

pH: determined by electrometric method in potentiometer using, 10g of mashed sample composed of four fruits diluted in 90mL of distilled water, in accordance with [5].

Titratable acidity (TA): determined using analyte (10g of the four-fruit pulp homogenized and diluted in 90mL), titrated with sodium hydroxide standard solution (NaOH) at 0.1N, having phenolphthalein as indicator. Results were expressed as malic acid percentage. All methodology used complies with [5].

2.4 Physiological Parameters

Amide: chemically extracted and spectrophotometrically determined according to a chemical method by [6]. It was determined at 510nm and results were expressed as percentage.

Total sugars (TS): extracted with ethyl alcohol and determined by the Antrona method [7]. The sample was subjected to reading on spectrophotometer at 620nm, and results were expressed as percentage.

Reducing sugars (RS): determined by Nelson's methodology [6]. Reducing sugar content was calculated by spectrophotometry at 510nm, and results were expressed as percentage.

Non-reducing sugars (NRS): obtained by differences between total sugars and reducing sugars, as per the formula below:

Non-reducing sugars = Total sugars – Reducing sugars x 0.95.

Electrolyte extravasation: it was determined according to [8]; a peel disc was removed per damaged area from each fruit of the bouquet, measuring 1cm in diameter, with the aid of a metal punch. This section was washed in distilled water and superficially dried on absorbent paper, then incubated for 2 hours in a capped test tube containing 18mL of distilled water, under ambient conditions. After this period, electrical conductivity was measured on a SCHOT conductivity meter, model CG 853. Later, the tubes containing the peel samples were autoclaved at 121^{o}C and 1.5atm for 30 minutes. After autoclaving, electrical conductivity was read again. Results were expressed as the ratio between values obtained in the first and second measurements multiplied by 100.

2.5 Experimental Design and Statistical Analyses

The experimental design employed was the completely randomized type (CRD), in a 5x5 factorial scheme, with five bunch ages (16, 17, 18, 19 and 20 weeks after inflorescence emission) and 5 assessment periods (1, 3, 5, 7 and 9 days after storage). Four repeats were used, and the experimental unit was composed of four fruits. Data on the variables were subjected to tests for analysis of homogeneity of variance [9], residue normality by the Shapiro-Wilk test[10] and model non-additivity [11].Results were then subjected to analysis of variance (ANOVA), considering as sources of variation bunch ages, assessment days after storage, and interaction between bunch ages and days after storage, tested at 5% probability. Interaction was sliced or not, depending on significance; regression analysis was conducted, and models were chosen based on significance, coefficient of determination and potential to explain the biological phenomenon. The variables were studied using statistical program SISVAR.

3. RESULTS AND DISCUSSION

Analyzing peel firmness, significant interaction was observed between bunch age and assessment day, factors that simulate the marketing period of fruits; fruits from bunches younger than 19 weeks were firmer on the 9th day after storage, presenting values of 17.39N, 21.36N, 20.86N and 15.77N, for bunch ages corresponding to 16, 17, 18 and 19 weeks, respectively; bunches with 17 weeks were superior to the other treatments, with longer shelf life (Figure 1).

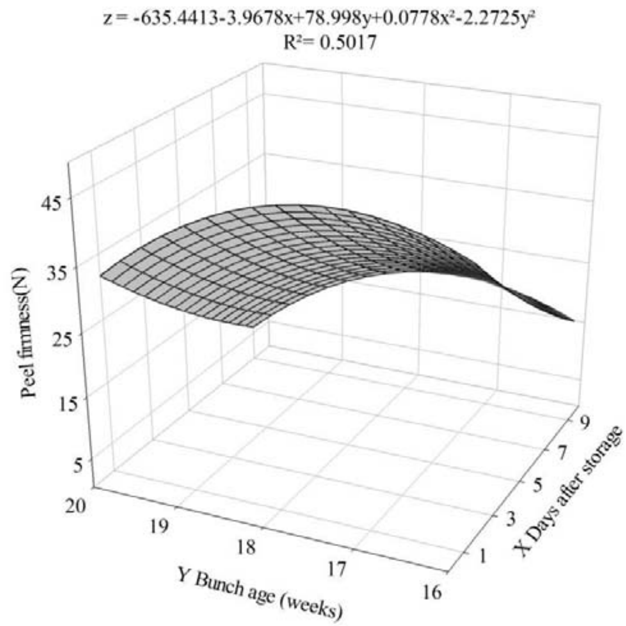

Figure 1: Peel firmness of banana 'Prata-Anã' harvested at different bunch ages against days after storage

On the other hand, 20-week bunches were less firm, reaching 6.15N on the last assessment day.[12], while working with banana 'BRS Tropical", found that fruits with greater development at the harvest point had reduced firmness. According to [13] and [14], firmness reduction is related to amide hydrolysis and solubilization of pectic substances, as well as to water loss.

As for pulp firmness, significant interaction was observed between bunch ages and storage days for this variable, which reduced as bunch age increased; on the first assessment day, for the ages of 16, 17, 18, 19 and 20 weeks, the values found were 19.36N, 18.27N, 17.18N, 16.10N and 15.01N, respectively (Figure 2). It was possible to observe on the days after storage a sharp firmness reduction in fruits harvested with 18, 19 and 20 weeks, which showed respective values of 2.83N, 1.74N and 0.70N, compared to those harvested with 16 and 17 weeks, which presented values of 5.00N and 3.92N, respectively; fruits from the bunch with 16 weeks were firmer than the others. The results of this experiment corroborate with study by [15], which related firmness loss of banana 'Prata-Anã' pulp to older bunch harvest age, stressing that high storage temperatures also contribute to firmness loss, and it is possible to observe that not even temperatures under 10°C were enough to prevent softening in fruits from 20-week bunches, that is, these fruits had a greater firmness loss.

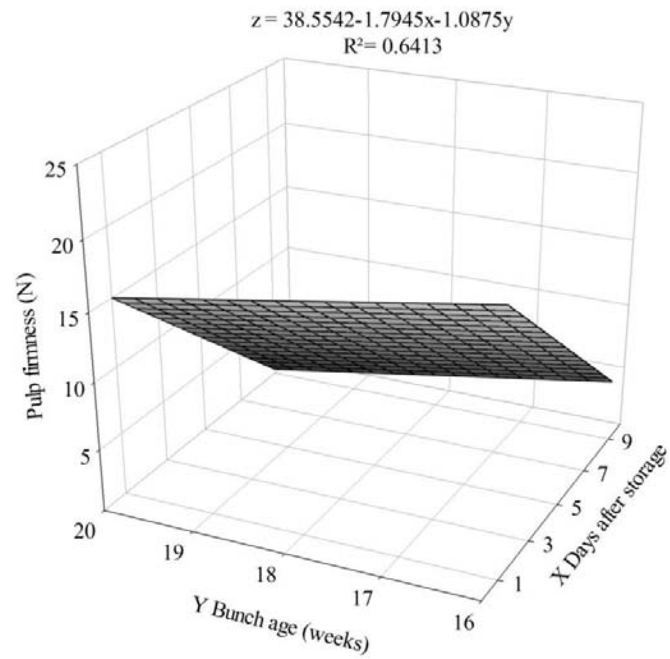

Figure 2: Pulp firmness of bananas ‘Prata-Anã’ harvested at different bunch ages against days after storage

For color-describing variables, the hue angle parameter defines the basic color of samples and represents the average hue of the banana samples; results were significant for interaction. The hue angle values found in the banana peels at different bunch ages (16, 17, 18, 19 and 20 weeks) dropped from 106.2°, 104.7°, 103.2°, 101.7° and 100.2° to 85.3°, 83.8°, 82.4°, 80.9° and 79.4°, respectively, with this drop occurring from the 1st to the 9th day after storage, which varied by treatment (Figure 3).This behavior is expected because hue angle values close to 100° presented a greenish color, and as values move further or closer to 80° the color of the fruit turns yellowish, evidencing ripening. Fruits harvested with a bunch age of 16 weeks had hue angle values higher compared to other ages on the last assessment day, indicating their preservation and allowing for them to be marketed for a longer period. According to [16], fruit color is an important parameter to track the ripening process, which, in the case of bananas, corresponds to yellow, due to chlorophyll degradation and carotenoid synthesis, besides being a criterion used to characterize maturation stages.

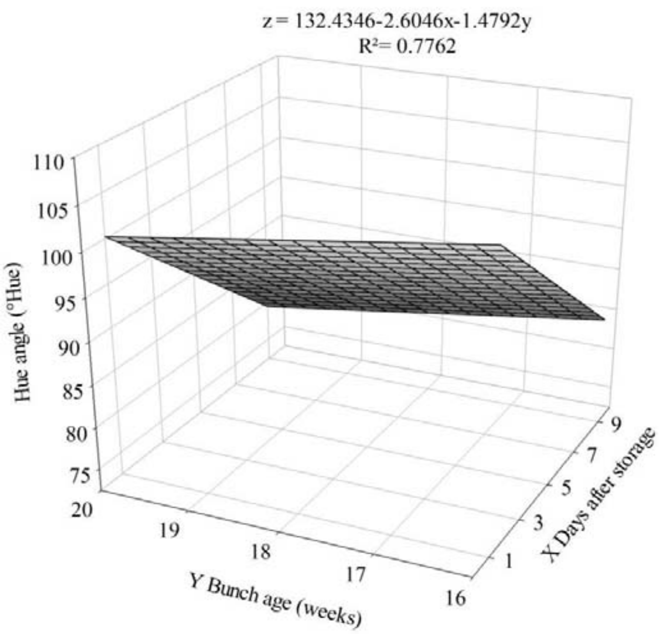

Figure 3: Hue angle (a) of bananas ‘Prata-Anã’ harvested at different bunch ages

Figure 4 displays chromaticity values, which express color intensity, that is, saturation in terms of pigment. Significant difference is observed between bunch ages; values stood at 37.64, 38.84, 40.04, 41.25 and 42.45 with 16, 17, 18, 19 and 20 weeks of age, respectively. These results are higher than those found by [3] while analyzing chromaticity in peels of banana ‘Prata-Anã’ stored at 10^{o}C, with 18, 19 and 20 weeks of development, finding estimated mean values of 33.67, 33.87 and 34.61, respectively.

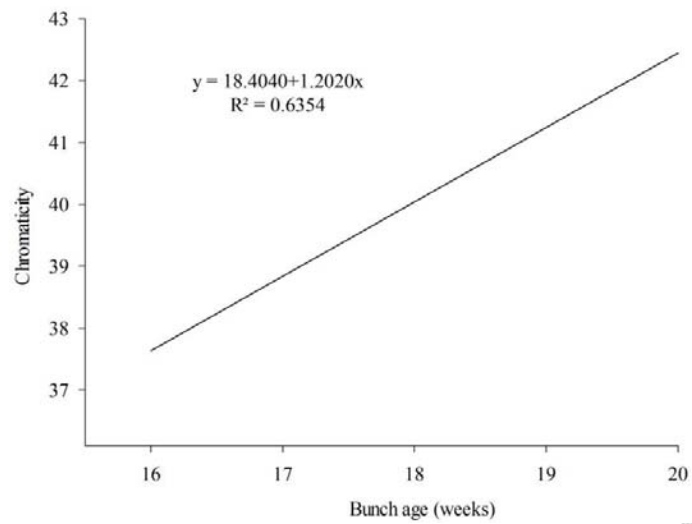

Figure 4: Chromaticity of bananas 'Prata-Anã' harvested at different bunch ages

The soluble solids variable presented significant interaction, being influenced by harvest ages and days after harvest. Figure 5 shows the behavior of soluble solid mean values, and it is possible to observe an increase in soluble solid content as fruits ripen; from the 1st to the 9thassessment day for all treatments (16, 17, 18, 19 and 20 weeks of bunch age), the values found were 4.08-16.73, 5.33-17.98, 6.88-19.53, 8.73-21.38, and 10.88-23.53^{o} Brix, respectively. Bananas have a high amide content when green and, as they ripe, amide is hydrolyzed into simple sugars for it to be used in fruit respiration, thus raising soluble solid content during maturation. The results observed on the last assessment day in the present experiment are similar to those found by [17] while working with fruits of banana trees 'Maravilha' and 'Preciosa', which showed values between 18.85 and 23.31 after cultivation during the 1st and 2ndproduction cycles, in the Upper Medium São Francisco River.

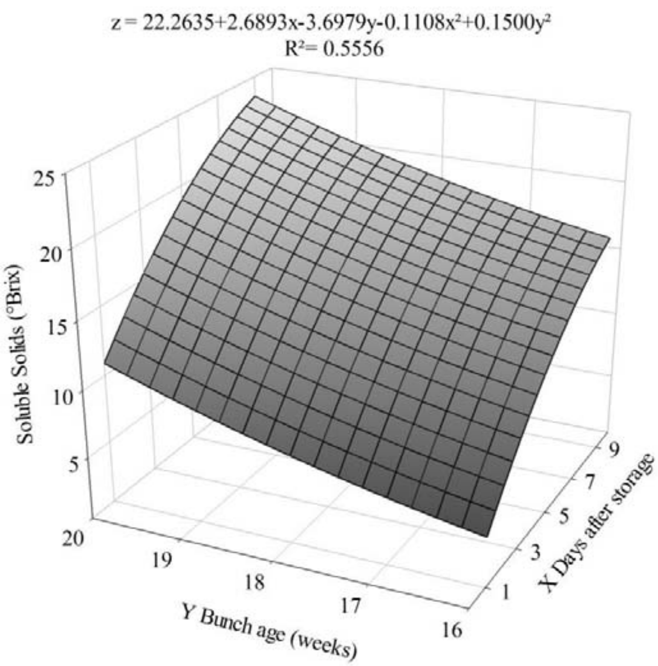

Figure 5: Soluble solid content in bananas 'Prata-Anã' harvested at different bunch ages against days after storage

There was significant interaction for pH between bunch ages and assessment days after storage. Figure 6 shows the behavior of values obtained for banana 'Prata-Anã' pH throughout the assessment days in relation to bunch ages. For all treatments, it is possible to observe a rapid decline in values obtained 9 days after storage, from 6.04 to 5.10, 6.07 to 5.14, 6.04 to 5.11, 5.94 to 5.01 and 5.78 to 4.84 for bunches with 16, 17, 18, 19 and 20 weeks, respectively. According to [18], while working with banana tree fruits, found pH values between 5.28 and 5.60, close to those found in the present study. [19], while working with bananas 'Prata-Anã' stored for 14 days under different controlled atmosphere conditions, found a mean pulp pH value of 4.25 after 3 days after atmosphere removal and maintenance in ambient atmosphere. According to[20], working with modified atmosphere associated with refrigeration in bananas, pH values in mature fruits varying from 4.2 to 5.0 were observed. According to [16], during the maturation phase of fruits there is an accumulation of soluble sugars, precursors of organic acids, with predominance of malic acid, which leads to a pH reduction throughout ripening.

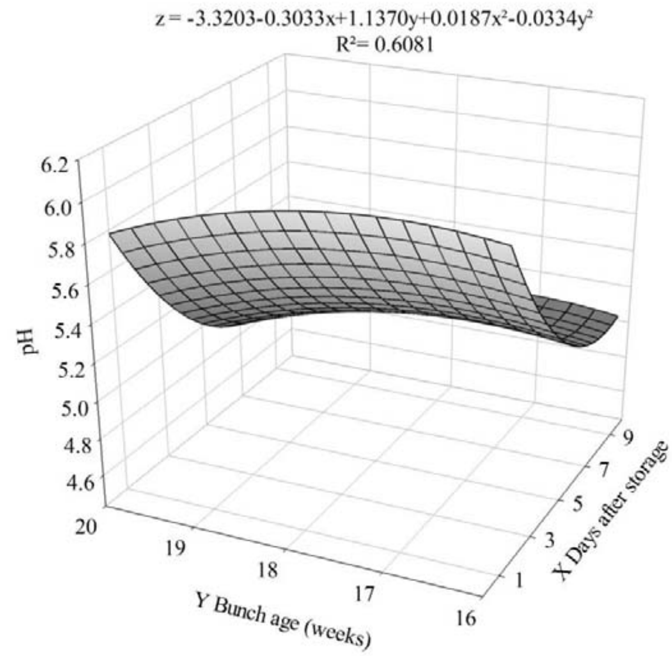

Figure 6: pH values in bananas 'Prata-Anã' harvested at different bunch ages against days after storage

Titratable acidity showed significant interaction and associated with increased malic acid concentration. The graph reveals an increase in malic acid content in all fruits as they ripen and the bunches becomes older. For the bunch ages of 16 and 20 weeks, 0.17g and 0.26g of malic acid were found per 100g of pulp, respectively, on day 1.On the 9th assessment day, which simulates the marketing period, it is possible to observe that the bunch age of 16 weeks presented a value of 0.40g, whereas the bunch age of 20 weeks presented a value of 0.49g of malic acid per 100g of pulp, superior to the other bunch ages, evidencing faster ripening and shorter shelf life (Figure 7). The mean titratable acidity values observed in the present study 9 days after storage were similar to those found by [21] while working with 'Prata-Anã' in two production cycles. These results are in line with [22] in that unripe bananas have low acidity, and during ripening this acidity slowly increases until reaching a maximum value when the fruit is ripe and later falls with its senescence. [23] obtained results superior to those found in this study, with 0.54g of malic acid per 100g of "Prata anã" banana pulp throughout the storage period. Organic acid decline has been attributed to respiration or sugar conversion that occurs when banana tree fruits are ripening. These acids provide a sugar-acid balance, which results in a more tasteful fruit when ripe [24].

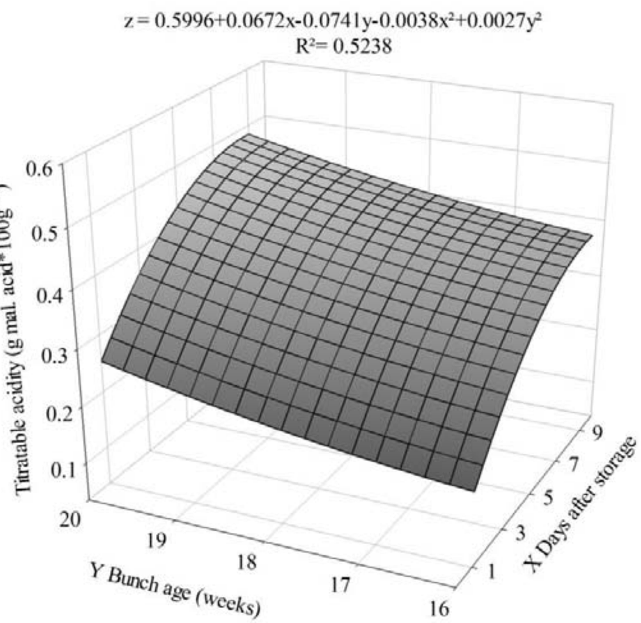

Figure 7: Titratable acidity content in bananas 'Prata-Anã' harvested at different bunch ages against days after storage

As for amide content, there was significant interaction as it was influenced by harvest seasons and days after storage in cold chamber (Figure 8). From the values obtained, a slight drop was seen in the amide content of the fruits as bunch age increased that is, bunches harvested later, because, as fruits ripen, amide rapidly degrades to be converted into sugars and may vary depending on bunch harvest season. According to [25], banana is a fruit with high amide content when unripe, and as it ripens, amide is broken into sugars for it to be used in the fruit's respiration, raising the content of soluble solids. [17], while studying physical and chemical characteristics of different banana tree fruits, observed differences between AAB group fruits; unripe bananas 'Prata-Anã' showed a value of 29.68%, close to that found in fruits with bunch age of 16 weeks and superior to the other ages.

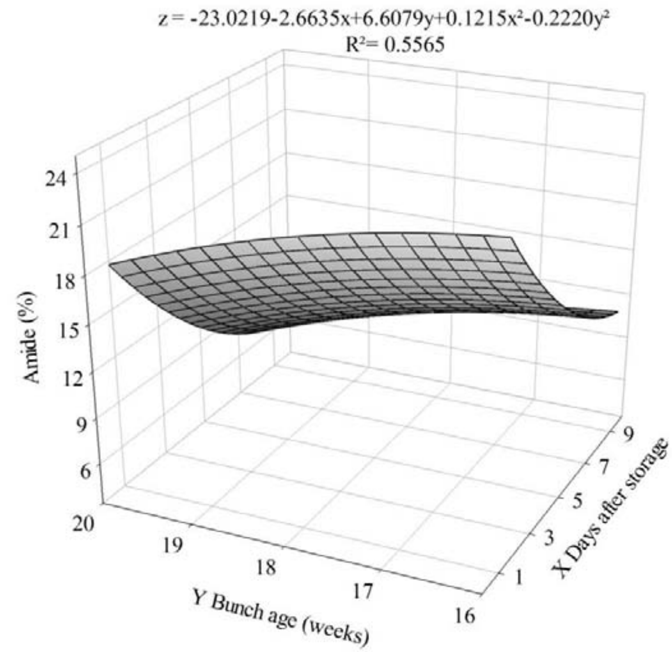

Figure 8: Amide content in bananas 'Prata-Anã' at different bunch ages against days after storage

For total sugar, significant difference was found between bunch ages and assessment days. Total sugar percentages were 6.60%, 7.95%, 9.29%, 10.64% and 11.98% for the ages of 16, 17, 18, 19 and 20 weeks, respectively (Figure 9). Bunch harvest age had a significant influence on amide and sugar content during storage. Concerning different assessment seasons, on days 1, 3, 5, 7 and 9 days after storage, there is a linear increase in sugar percentage, with values at 1.61%, 5.45%, 9.29%, 13.14% and 16.98% (Figure 10). The results found in this study are lower than those observed by [26], who also reported an increase in total sugar values over the evaluation days, ranging from 4.05% to 25%. According to [17], while amide is hydrolyzed, there is an increase in total sugar content, which makes fruits ripe and sweet. The main sugars found in ripe banana pulp are glucose, fructose and sucrose.

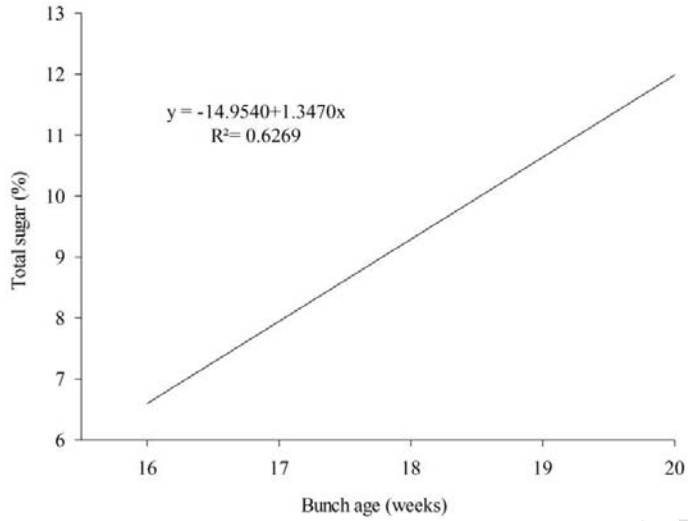

Figure 9: Total sugar in bananas 'Prata-Anã' harvested at different bunch ages

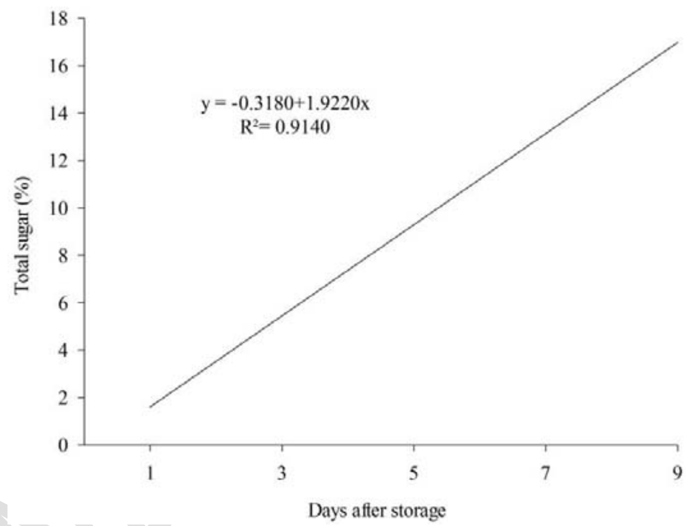

Figure 10: Total sugar in bananas 'Prata-Anã'on days after storage

Significant results were observed in interaction for the reducing sugar variable. As of the first assessment, it is possible to observe a slight percentage increase in reducing sugar for all treatments; however, concerning fruits from bunches with 16 weeks, they reached a lower value than the other treatments – 9.62%.Treatment with the ages of 17, 18, 19 and 20 weeks presented higher values – 10.13%; 10.63%; 11.15% and 11.65%, respectively –; age increase resulted in sugar increase, and lower sugar percentage in the fruits was found in 16-week bunches (Figure 11). [27], while working with climatization of banana 'Prata-Anã', also found increases in reducing sugar content during ripening, arguing that such increase was due to insoluble molecule interconversion, such as non-reducing sugars into depolymerized sugars and then soluble sugars.

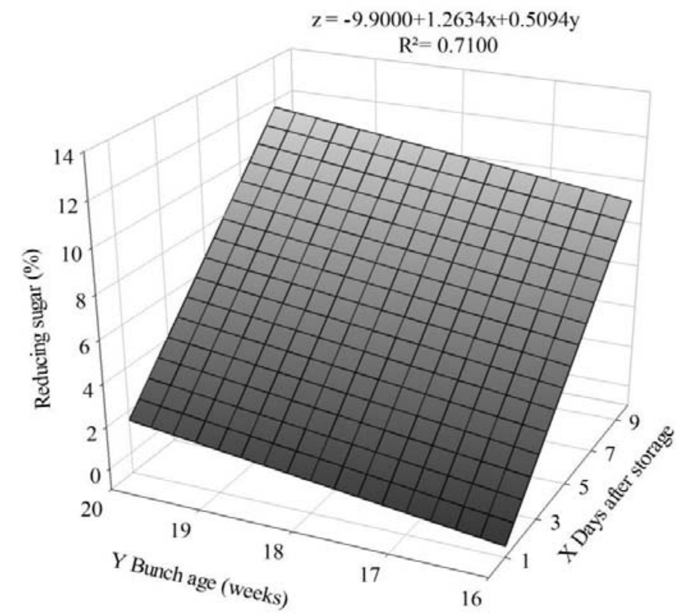

Figure 11: Variation of reducing sugar content in bananas 'Prata-Anã' harvested at different bunch ages against days after storage

For non-reducing sugar, significant difference was found between assessment periods, that is, 1, 3, 5, 7 and 9 days after storage, with values being 1.02%, 2.27%, 3.52%, 4.77% and 6.02%, respectively (Figure 12). According to [28], while working with 10 banana genotypes (Pacovan, PV 04-44, PV 03-76, 'Prata-Anã', 'Fhia-18', 'Pioneira', 'Prata-graúda', 'Caipira', 'Nanica', 'Thapmaeo'), found non-reducing sugar values for banana 'Prata-Anã' of 1.3 ± 0.21%, which are lower than those found in the present study.

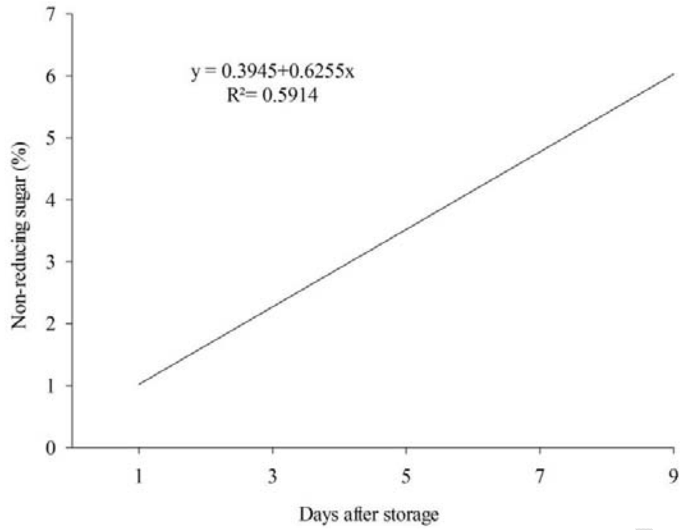

Figure 12: Variation of non-reducing sugar content on days after storage

The fruits'electrolyte extravasation percentage had significant difference between bunch ages and assessment days. There was an increase on the days after storage, reaching values close to 37% on the 9th assessment day (Figure 13). Thus, fruits at a more advanced maturation stage tend to lose membrane integrity and have a faster electrolyte extravasation compared to those at an earlier maturation stage [29]. According to [30], working with "Prata-Anã" banana submitted to hydrothermal treatment, the same behavior was observed, increased extravasation of electrolytes throughout the days after fruits were removed from the cold chamber, regardless of immersion temperature. Significant difference was found between treatments; although variation between some treatments was small, fruits from 16-week bunches presented lower electrolyte extravasation percentage compared to the other treatments, with a value of 17.72% (Figure 14). As shown by the results of this experiment, the fruits' greater resistance is due to lower cell membrane degradation, estimated by electrolyte extravasation percentage.

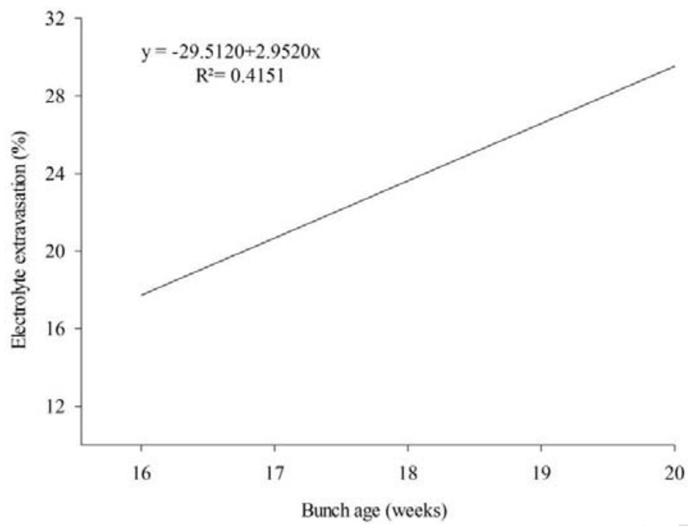

Figure 13: Electrolyte extravasation of bananas 'Prata-Anã' against bunch age

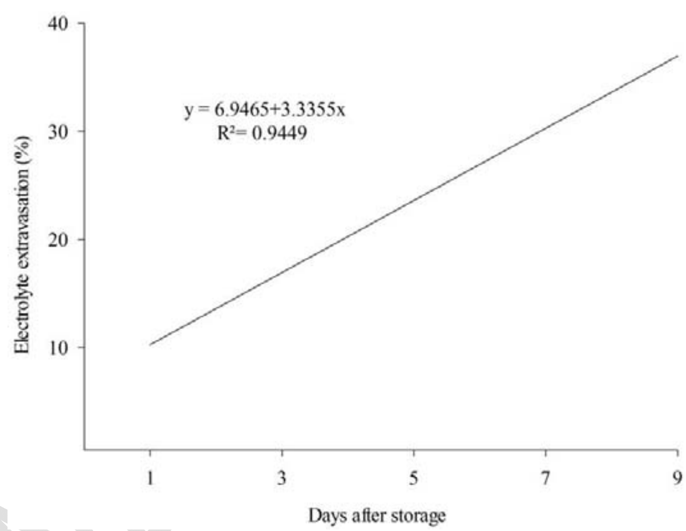

Figure 14: Electrolyte extravasation of bananas 'Prata-Anã' against days after storage

4. CONCLUSIONS

Bunch harvest age had direct influence on post-harvest quality of 'Prata-Anã' banana. Fruits from 16-week bunches stored at 10°C ± 1°C and relative humidity of 90% +5% for 25 days were superior for physical and chemical characteristics compared to other ages, leading to longer post-harvest life.

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