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Original Paper

Postharvest technologies in the ripening of 'Maçã' bananas stored in ambient condition

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Abstract

The banana is a climacteric fruit with a limited shelf life in the environment and sensitive to storage under refrigeration, necessitating strategies to improve its post harvest conservation. In this sense, the objective of this study was to evaluate the effect of post harvest technologies on the quality and the prolongation of the useful life of 'Maçã' bananas during storage in ambient temperature condition (25 ºC). The fruits were obtained in physiological maturity in the green color and immersed in the following solutions: distilled water (control), cassava starch, maize starch and 3% calcium chloride for three minutes in addition to the sachets containing 3g KMnO4 for one period of 12 days in ambient condition. The evaluations took place every three days in terms of loss of fresh weight, firmness of peel, starch content, soluble solids, titratable acidity, pH, SS/AT ratio and incidence of rot. The postharvest treatments extended the shelf life of the fruits for 12 days in relation to the nine days of the control treatment. Among the evaluated technologies, the use of sachets of KMnO4 delayed ripening by observing fruits with higher green retention of the peel and pulp firmness, as well as lower fresh mass loss, starch degradation, soluble solids synthesis, ratio SS/AT and incidence of rot during the storage period. Thus, the ethylene absorber based on KMnO4 represents a viable alternative for the preservation of the quality of 'Maçã' bananas during commercialization at room temperature.

Key-words: *Musa* sp., Ethylene Absorber, Calcium Chloride, Edible Coatings, Fruit Quality

Introduction

Banana (*Musa* sp) is a tropical fruit widely consumed in the world and Brazil stands out in this scenario as the fourth largest producer in the world, with 6.8 million tons produced in 2018 (Agrianual, 2019). However, despite its large production and consumption, the banana has a high index of post-harvest losses, which limits its commercialization in the form "*in natura*" (Sousa et al., 2018).

Characterized as a climacteric fruit the banana presents a fast and irreversible maturation that is accompanied by significant changes in the physical and chemical attributes (Mohapatra et al., 2010; Alkarkhi et al., 2011) limiting the shelf life of 6 to 8 days at room temperature (Huang et al., 2014), also does not tolerate temperatures below 13 °C precluding refrigerated storage due to the occurrence of cold or chilling injury (Nguyen et al., 2003; Kumari et al., 2017).

In this sense, the search for strategies to improve the post-harvest conservation of bananas such as the use of edible coatings based on starch, calcium chloride and sachets of ethylene ($KMnO_4$) are alternatives to increase the useful life of the fruit.

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Coatings with cassava starch and corn, for example, are inexpensive and edible and are capable of forming a thin layer of biodegradable plastic on the plant tissue, making it an efficient barrier against water loss, visual aspect of the fruits for commercialization (Luvielmo and Lamas, 2012) as already observed during the storage of fruits, such as: banana (Silva et al., 2015), tomato (Menezes et al., 2017), dragon fruits (Sanches et al., 2017a), among others.

Calcium is considered the most important nutrient in determining the quality of the fruits, its use in pre and postharvest has several benefits, being able to reduce the softening and senescence, thus maintaining the quality of the same in the period of storage and shelf (Gayed et al., 2017) where the studies that indicate the use of calcium chloride ($CaCl_2$) to increase the useful life of tropical fruits (Sanches et al., 2017b; Sanches et al., 2017c; Oliveira Júnior et al., 2018)

However, the use of ethylene absorbers based on potassium permanganate ($KMnO_4$) has been efficient in the elimination of this phytohormone inside the packages (Wills and Warton, 2004; Campos et al., 2007), thus retarding the ripening of various climacteric fruits (Brackmann et al., 2010; Bal and Celik, 2010; Pimenta et al., 2013; Nasser et al., 2015; Falcão et al., 2017). In general, sachets containing potassium permanganate ($KMnO_4$) promote the oxidation of ethylene to water, carbon dioxide, manganese dioxide and potassium respectively (Wills and Warton, 2004; Wills et al., 2014) and, because it is not volatile, it can be physically separated from the product, eliminating the risk of chemical contamination (Sá et al., 2008).

The objective of this study was to investigate the use of different technologies for postharvest conservation in the ripening control and conservation of 'Maçã' banana stored at room temperature (25 ºC).

Material and methods

Plant material

Fruits of banana (*Musa* sp) cv. Maçã obtained at the Altamira-PA local trade and transported in plastic boxes to the Product Technology Laboratory of the Federal University of Pará, Campus Altamira, PA, where they were plucked and sanitized in chlorinated solution (5 $mL.L^{-1}$) for 1 minute and dried under room temperature (25 °C).

Preparation, coatings application and storage

For the preparation of the solutions with cassava starch and corn starch at a concentration of 3%, 30 g of the samples were dissolved in 1 L of distilled water with subsequent heating in a water bath at 70 ºC, under constant agitation until the gelling point. After resting until reaching room temperature the fruits were immersed in the solution for a period of three minutes.

The calcium chloride solution ($CaCl_2$) was prepared by diluting 30 g of the product in 1 L of distilled water followed by immersion of the fruits for three minutes. Potassium permanganate ($KMnO_4$) was prepared by incorporating 30 g of the product into 1 kg of vermiculite which, after homogenization, was formed into sachets with 3g of the mixture. The sachets (1 und) were distributed among the fruits of each experimental plot.

After application of the solutions and the distribution of the sachets, the fruits were stored in styrofoam polystyrene trays, identified and stored at room temperature (25 °C ± 90% U.R) for a period of 12 days.

Physicochemical analysis

The fruit quality analyzes were determined every three days over 12 days of storage on the following variables:

Fresh weight loss: determined using a precision analytical balance (0.1 g), calculating the difference between the weight on the day of installation of the experiment and the respective day of analysis, and the results expressed as a percentage (%).

Firmness of the fruits: measured through sensorial analysis composed of seven trained evaluators who attributed notes in a hedonic scale of five points, where: 1 - soft; 2 - slightly soft; 3 - slightly firm; 4 - moderately firm and 5 - firm (Menezes et al., 2018).

Shell coloration: determined by visual analysis by seven trained assessors who assign grades on a hedonic scale of five points (CEAGESP, 2009) with modifications, where: 5 - green; 4 - greener than yellow; 3 - more yellow than green; 2 - yellow and 1 yellow with brown areas.

Starch content: determined by the iodine-starch method visually analyzing the color of the sample and assigning notes on a five-point hedonic scale with modifications, where: 5 - dark tissue, completely

dyed; 4 - up to 10% of the surface with whitening; 3 - up to 25% of the surface with bleaching; 2 - up to 50% of the surface with whitening and 1 - surface with more than 75% of whitening (Girardi et al., 2002).

Soluble solids (SS): determined using a digital refractometer of the brand (ABBE Refractometer) using a 1 mL aliquot of the pulp juice of the fruits and the results expressed in ºBrix (AOAC, 2012).

Titratable acidity (TA): measured by the titrator method (AOAC, 2012) with 0.01 M sodium hydroxide (NaOH) and 1% phenolphthalein as a turning point indicator. In an erlenmeyer flask 10 ml of the sample was pipetted followed by homogenization with 50 ml of distilled water and addition of 3 drops of phenolphthalein. The 25 ml burette volume was quenched with 0.01 M NaOH and thus titrated until the sample reached a pink color and the results were expressed as % malic acid.$100g^{-1}$ of pulp. pH: determined using 10 g of the sample macerated and homogenized in 50 mL of distilled water followed by a bench reading (TECNOPON, version 7.1), previously calibrated with buffer solutions pH 4.0 and 7.0 (AOAC, 2012).

Incidence of rot: determined visually by seven trained evaluators who assigned grades on a hedonic scale of five points, where: 5 - 0% of rot; 4 - up to 5% of affected fruits; 3 - up to 25% of affected fruits; 2 - up to 50% of affected fruits and 1 - more than 50% of fruits affected (Menezes et al., 2018).

Experimental design and Statistical analysis

A completely randomized design was used in a 5x5 factorial arrangement that corresponds to five treatments (control, cassava starch, corn starch, calcium chloride and potassium permanganate 3%) and five storage/evaluation times (0, 3, 6, 9 and 12 days) with three replicates and the experimental plot composed of five fruits. The data of each variable were submitted to analysis of variance (ANAVA) and the means were compared by Tukey test ($p < 0.05\%$) using the statistical software SISVAR 4.3.

Results and discussion

The postharvest treatments adopted resulted in increased shelf life (12 days) in relation to the fruits of the control treatment (9 days) characterized by senescence/rot.

There was a significant ($p<0.05$) effect of postharvest treatments on fresh weight loss and fruit firmness over the storage time (Figure 1A and 1B), respectively.

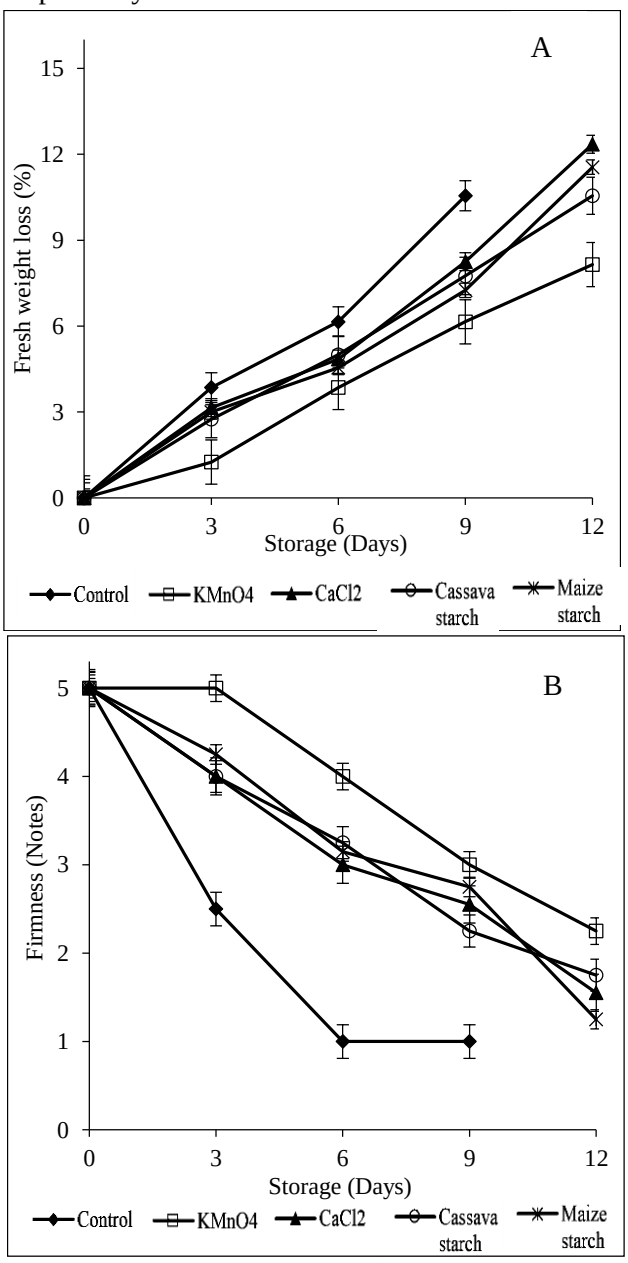

Fig. 1. Fresh weight loss (A) and firmness (B) in 'Maçã' bananas and stored under ambient conditions (25 °C) for a period of 12 days. $KMnO_4$ = potassium permanganate, $CaCl_2$ = calcium chloride.

Fresh weight loss occurred in the fruits of all evaluated postharvest treatments, however, fruit packing with potassium permanganate sachets showed the lowest percentage (7.26%) after 12 days of storage differing ($p<0.05$) in relation to the other treatments, especially in the fruits of the control treatment, whose loss was over 9% after nine days of storage (Figure 1A).

This lower mass loss in the fruits packed with $KMnO_4$ sachets may be related to the removal of the catalytic ethylene inside the packages, thus retarding the metabolic processes related to ripening, among them the transpiration rate of the fruits.

Considering that in the commercialization of the banana the fruit mass is an important factor, and it can still compromise the visual appearance of the fruit (Sarmento et al., 2015) the preservation of this characteristic with the use of $KMnO_4$ sachets is an alternative during storage in condition environment.

Similarly, fruit firmness reduction occurred in all postharvest treatments (Figure 1B) as a result of fruit transpiration through the reduction of fresh mass/turgescence (Figure 1A) and maturation through enzymatic degradation of molecules (pectin, cellulose, hemicellulose) that constitute the cell wall leading to the softening of the pulp.

In this sense, the greatest loss of firmness is observed in the control fruits being characterized with note 1 (soft) already in the sixth day of storage. On the other hand, fruits packed with potassium permanganate sachets remained firm in relation to the other treatments ($p<0.05$) receiving note 3 (slightly firm) after 12 days of storage (Figure 1B).

The use of sachets containing vermiculite impregnated with $KMnO_4$ in the concentration of 5%, maintained the fruits of banana cv. Grand Naine firmer over 24 days at 18 °C (Sarkar et al., 2017).

The color of the bark was altered with storage time and post-harvest treatments ($p<0.05$) (Figure 2).

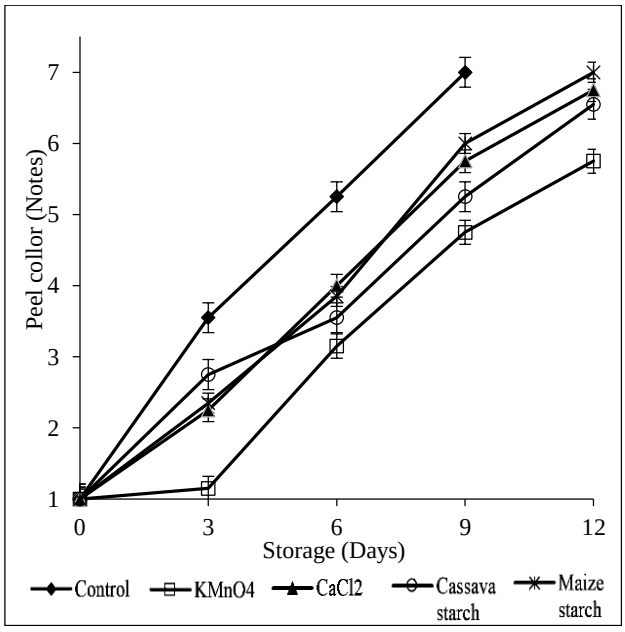

Fig. 2. Peel collor in 'Maçã' bananas and stored under ambient conditions (25 °C) for a period of 12 days. $KMnO_4$ = potassium permanganate, $CaCl_2$ = calcium chloride.

The changes in the color of the fruit peel result from the ripening through the degradation of chlorophyll and the synthesis of colored pigments. In this work chlorophyll degradation was lower in the fruits packed with permanganate sachets, considering that on the 12 days the fruits were characterized with a note 3 (more yellow than green) differing significantly ($p<0.05$) in relation to the other treatments (Figure 2).

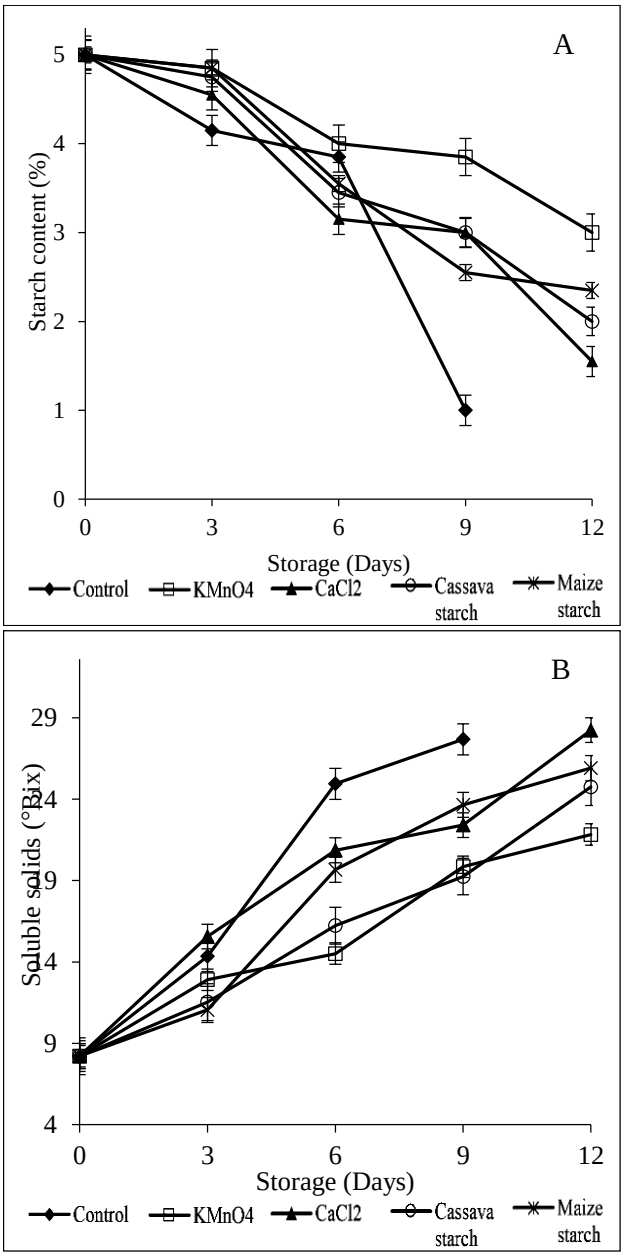

Fig. 3. Starch content (A) and content of soluble solids (B) in 'Maçã' bananas and stored under ambient conditions (25 °C) for a period of 12 days. $KMnO_4$ = potassium permanganate, $CaCl_2$ = calcium chloride.

This result can be justified by the action of $KMnO_4$, which, when absorbing the ethylene that surrounds the fruit, delays the ripening and,

consequently, the degradation of chlorophyll. On apples 'Royal Gala' (Amarante and Steffens, 2009) and bananas 'Grand Nine' (Sarkar et al., 2017) the use of sachets with 5 and 10 g of $KMnO_4$, delayed the degradation of the bark/chlorophyll color, respectively, when compared to the control fruits with direct reflection in the useful life of the fruits (ripening).

Fruit packing with $KMnO_4$ sachets also delayed the degradation of the starch (Figure 3A) and the synthesis of soluble solids (Figure 3B) in relation to the other treatments ($p<0.05$) with storage time.

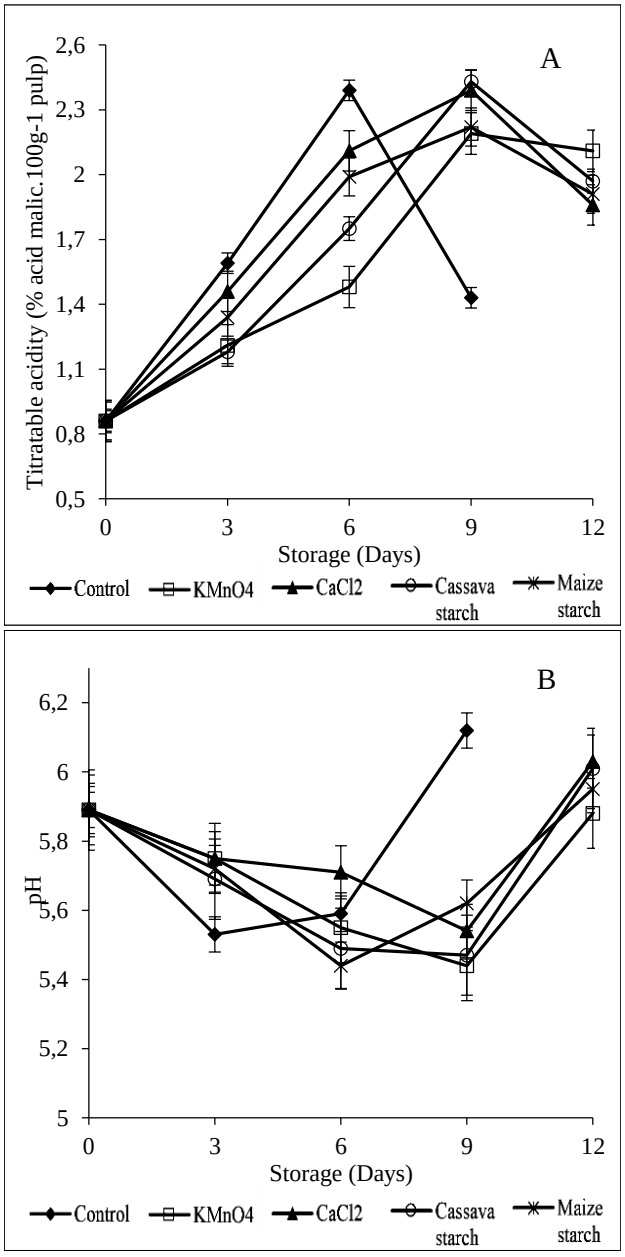

Fig. 4. Titratable acidity (A) and pH (B) in 'Maçã' bananas and stored under ambient conditions (25 °C) for a period of 12 days. $KMnO_4$ = potassium permanganate, $CaCl_2$ = calcium chloride.

This decrease in starch content (Figure 3A) and increase in soluble solids (SS) content (Figure 3B) with storage time is justified by the metabolization of carbohydrates and conversion to simple sugars by tasting the sweetest fruits with the sweetening.

In general, the most significant increase in SS content is observed in control fruits (25.6 °Brix) at the end of nine days of storage (Figure 3B) indicating fruits with more advanced stage of maturation due to higher carbohydrate degradation, 1.0 (surface with more than 75% bleaching) (Figure 3A).

On the other hand, fruits packed with $KMnO_4$ sachets showed delay in ripening, resulting in lower SS content (20.7 ºBrix) and higher starch content 3.0 (up to 25% of the surface with bleaching) differing ($p<0.05$) in relation to the other treatments.

These results corroborate those observed in mangabas (Nasser et al., 2015), bananas 'Prata Anã' and 'Grand Nine' (Falcão et al., 2017) and nectarines (Jayarajan and Sharma, 2018), where the use of sachets impregnated with $KMnO_4$, independent of the concentration, delayed the ripening of the fruits through the lower synthesis of sugars (soluble solids) throughout the storage.

Titratable acidity (Figure 4A) and pH (Figure 4B) presented an inversely proportional behavior, as the percentage of acidity increased, the pH decreased with a significant difference ($p<0.05$) between treatments with the storage time.

For the titratable acidity (AT), an increase with peak at the sixth day (2.39% malic acid.$100g^{-1}$ pulp) was observed for the control fruits and at nine days (~2.15% malic acid.$100g^{-1}$ pulp) for the other post-harvest treatments, with subsequent reduction on the 9th and 12 day of storage, respectively. This behavior suggests that the post-harvest treatments delay the degradation of the organic acids (ripening) in relation to the fruits of the control treatment.

The titratable acid content for banana grows with its ripening, and it decreases when the fruit is very ripe or at the stage of senescence. This occurs due to the solubilization of pectic substances and the consumption of acids during the respiratory peak characteristic of the senescence fruit (Bleinroth, 1990; Prill et al., 2012), this fact justifies the variation in the contents of TA observed during the storage of the fruits of this study.

According Chitarra and Chitarra (2005) pH values decrease after banana harvest and increase at the end of ripening or beginning of fruit senescence, which corroborates that observed in this study where the initial pH (5.81) reached 6.12 at nine days in the

control fruits and a (~5.98) in post-harvest treatments at the end of 12 days.

Potassium permanganate sachets treatment significantly influenced ($p<0.05$) maturation over flavor ratio and senescence (fruit rot) with storage time (Figures 5A and 5B), respectively.

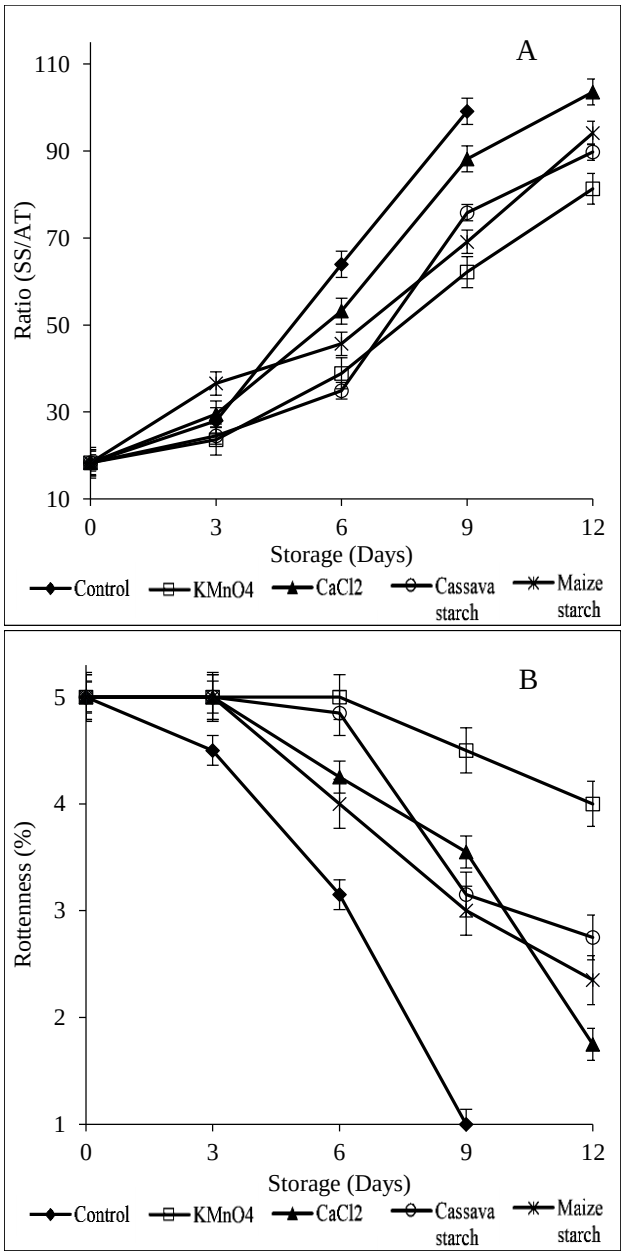

Fig. 5. SS / AT ratio (A) and incidence of rot (B) in 'Maçã' bananas and stored under ambient conditions (25 °C) for a period of 12 days. $KMnO_4$ = potassium permanganate, $CaCl_2$ = calcium chloride.

The ripening enhances the sweet taste through the relationship between soluble solids (SS) and titratable acidity (TA). This fact justifies the increase in the SS/AT ratio during the fruit storage period (Figure 5A).

In the ripe fruits of this study, the mean value in the SS / AT ratio was around 95.00, in contrast to the one obtained by Pereira (2011) when evaluating 'Maçã' bananas whose average value was 84.00, however, the edaphoclimatic conditions directly influence this flavor relationship.

According to Figure 5A, a significantly lower relation ($p<0.05$) was observed in bananas conditioned with $KMnO_4$ average of 81.32 in relation to the other treatments (~ 90,15). This lower SS/AT ratio indicates that the fruits are at a less advanced stage of maturation, corroborating that observed in the peel color (Figure 2) and, mainly, the lower consumption of soluble solids and organic acids (Figures 3B and 4A), respectively.

The lowest incidence of rot was also observed in fruits treated with $KMnO_4$ sachets differing ($p<0.05$) in relation to the other treatments, so that at 12 days they were characterized with a grade of 4.25 (up to 5% of rot) (Figure 6B). In the other treatments (cassava starch, corn starch and calcium chloride) the mean score was 3.0 (up to 25% of the area with rot), while in the control treatment the fruits were in complete senescence/rot stage with nine days of storage.

Conclusion

The packaging of bananas cv. Maçã with potassium permanganate sachets ($KMnO_4$) is the postharvest technology that best preserves the physicochemical characteristics of the fruit over 12 days of storage under ambient conditions (25 °C).

Conflict of interest: All authors declare no conflict of interest.

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