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Combination effect of citric acid and hot water treatment on the quality of pulp and pericarp of rambutan fruit

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ABSTRACT

Purpose: The oxidation of pericarp is the main one that affects the quality and acceptance of rambutan by consumers, thus, this study aimed to evaluate the isolated and combined effect of hot water and citric acid on the postharvest quality of pericarp and pulp of rambutan stored under refrigeration. **Research method:** Ripe fruits were immersed in a solution with hot water (45°C in 1 and 3 minutes), citric acid (1 and 3%), and in combinations between them. After the treatments, the loss of mass, soluble solids, titratable acidity, pH, vitamin C content, and browning of the pericarp and pulp was evaluated every three days during 12 days of cold storage (10°C). **Findings:** The combined effect of hot water for 3 minutes with 3% citric acid resulted in better quality fruits (less mass loss, less degradation of soluble solids, organic acids, and vitamin C), in addition to delaying the development of browning pericarp and pulp until the sixth day of storage. **Limitations:** Investigations of oxidizing enzymes were absent (equipment) to support the study results. **Originality/Value:** Studies involving accessible and low-cost technologies that limit physiological damage after harvest (browning of the pericarp) and preserve the quality of the rambutan are recommended. Thus, the pretreatment of rambutan with hot water for 3 minutes associated with 3% citric acid is indicated to preserve the quality of the fruit during refrigerated storage (10°C) for 12 days.

INTRODUCTION

The rambutan (*Nephelium lappaceum* L.) is a fruit originally from Malaysia,belonging to the Sapindaceae family and widely distributed in Southeast Asia, but also with production in Australia, South Africa, Mexico and Brazil (Andrade et al., 2017). The fruits, when ripe, have red, yellow-orange exocarp, covered by flexible spines and translucent pulp (aryl), varying in color from white to light yellow, juicy, sweet and rich in vitamin C, being consumed fresh and in the form processed (jellies, jams, crystallized) (Santiago et al., 2019).

In Brazil the cultivation of rambutanzeiro is highlighted in states like Bahia, Pará, Amazonas, Rondônia and Acre (Andrade et al., 2017). In 2016, the amount of fresh fruit sold was 22.4 t, demonstrating the market potential for consumers and producers (Barreto et al., 2015; GEAGESP, 2016). However, postharvest quality is a limiting factor with an estimated useful life of up to 5 days when stored at room temperature (Hajar et al., 2017; Manjunath et al., 2018) and 12 days when stored under refrigeration (7-10ºC) since they are susceptible to chilling injury (Setyadjit et al., 2018; Sanches et al., 2018). The oxidation of the pericarp, the shrinkage, and darkening of the thorns caused by the excessive loss of water culminate in cracks in the skin and the occurrence of diseases that compromise its appearance, also, the released juice and the softening of the pulp are factors that affect the acceptance of the consumer (Supapvanich, 2015). In this sense, the search for accessible and low-cost conservation technologies for producers and consumers is essential to reduce losses rambutan postharvest. Thus, hydrothermal treatment is easy to use and in a short period, in addition to being a chemical-free method on fresh produce (Matias et al., 2012) and capable of promoting the inactivation of browning-promoting oxidase enzymes in vegetable (Souza et al., 2010). Citric acid restricts the development of diseases, prevents browning, reduces respiratory activity, and loss of fresh mass, thus preserving quality during storage (Patrignani et al., 2015).

In an attempt to minimize the oxidative damage caused to the peel and preserve the quality of the fruits during storage, this study aimed to evaluate the combined effect of citric acid and the treatment with hot water on the postharvest quality of rambutan stored under refrigeration (10ºC).

MATERIALS AND METHODS

Plant material

Rambutan fruits were harvested at physiological maturity in an orchard grown in the municipality of Uruará, State of Pará. The fruits were packed in a thermal box and transported to the Product Technology Laboratory of the Federal University of Pará, Campus Altamira, Pará, where they were selected for the absence of physiological defects, affected by pests or diseases and physical damage, and subsequently sanitized in 3 $mg.L^{-1}$ chlorinated solutions for 3 minutes.

Treatment application and storage

The treatment with hot water was carried out in tanks with controlled temperature (45 ºC) (Matias et al., 2012) and the fruits were immersed for 3 and 5 minutes. The citric acid (Sigma-Aldrich®) 1 and 3% ($w.v^{-1}$) were diluted in distilled water and the fruits were immersed in the respective solutions. The combined treatment of hot water and citric acid was carried out by immersing the fruits in heated water containing citric acid. After the application of the treatments, the fruits were dried under ventilation and placed in expanded polystyrene trays

and sealed with 0.020mm polyvinyl chloride film containing five fruits (about 150 grams) and stored in a cold chamber 10 ± 1.0ºC and 90 ± 5.0% RH for 12 days.

Physico-chemical and sensory analysis

Weight loss

Determined by weighing the fruits using a precision scale (0.1 g) by calculating the difference in mass on the initial day and that obtained for each evaluation period and the results were expressed as a percentage (1) (%).

$$WL\ (\%) = (pi - pf/pi) \times 100 \quad (1)$$

Where: WL = weight loss (%), Pi = initial fruit weight, Pf = weight in the period after the initial.

Total Soluble solids

Determined by refractometry using a 10 g grinding of the fruit pulp and a digital refractometer of the brand Atago, model N-1α, with reading in the range of 0 to 95 ° Brix, and the results were expressed in ° Brix (AOAC, 2012).

Titratable acidity

Determined by the titration of 10 mL of homogenized juice through a Mix (brand name Walita 400 Watt) with 90 mL of distilled water. 0.2 N NaOH solution was used as the titrant by adding three drops of 1% phenolphthalein as an indicator to the sample. The results were expressed as eq.mg citric acid.100 mL^{-1}.

pH

Determined using a digital potentiometer (model AK 90) calibrated with buffer solutions 4.0 and 7.0 using 10 g of homogenized fruit pulp with 50 mL of distilled water (AOAC, 2012).

Vitamin C

It was determined according to IAL (2008). The Tillmans solutions (2.6 diphenol-indophenol (DFI) 0.02%), 0.5% oxalic acid and ascorbic acid (AA) µg.ml^{-1} were initially prepared. The pulp (10 g) was homogenized with 30 ml of the oxalic acid solution and then filtered for titration. The concentration of vitamin C was calculated by the equation: V x F x 100 / A = mg of ascorbic acid per 100mL of the sample, where: V = volume of the Tillmans solution needed to achieve a pink color (L); F = factor of the Tillmans solution; A = ml of the sample used. The values were transformed into mg AA per 100g of fresh weight.

Browning of the pericarp and pulp

It was evaluated on a five-point hedonic scale, where: 5 = 100% red; 4 = up to 10% of the dark pericarp; 3 = up to 25% of dark pericarp; 2 = up to 50% of the dark pericarp and 1 = fruits with totally dark pericarp (Sanches et al., 2018). For the pulp, 5 = no browning; 4 = 5% browning; 3 = 10% browning; 2 = 25% browning and 1 = 50% browning pulp (Manjunath et al., 2018). Note 3 was considered the limit for the commercialization and quality of the fruits, respectively.

Experimental design and statistical analysis

The experiment was conducted in a completely randomized design under a 9x5 factorial scheme corresponding to nine treatments (T1: control; T2: hot water 3 minutes; T3: hot water 5 minutes; T4: citric acid 1%; T5: citric acid 1% + water hot 3 minutes; T6: citric acid 1% + hot water 5 minutes; T7: citric acid 3%; T8: citric acid 3% + hot water 3 minutes and T9: citric acid 3% + hot water 5 minutes) and five times of evaluation (0, 3, 6, 9 and 12 days) with four repetitions of 5 fruits.

The data were submitted to analysis of variance (ANOVA) and the comparison of means by the Tukey test ($p<0.05$) with the aid of the statistical software Assistant 7.7 beta version.

RESULTS AND DISCUSSION

Weight loss

There is a gradual increase in the loss of fresh fruit weight, regardless of the treatment with the storage time (Fig. 1). In general, untreated fruits (control) and hot water for five minutes showed a higher percentage of mass loss (8.03 ± 0.34 and 7.88 ± 0.21%), respectively about the other treatments ($p<0.05$), especially those with 3% citric acid (5.63 ± 0.23%) and a combination of 3% citric acid + hot water 3 min (5.12 ± 0.18%) at the end of 12 days of storage.

The increase in weight loss observed in this study is associated with reactions of respiratory metabolism and fruit sweating, which reduce the amount of water in the tissue and, rambutan is a fruit prone to sweating, especially for the account of the thorns that cover the pericarp (O'hare, 1995; Chitarra & Chitarra, 2009). In this sense, the combination of citric acid 3% + hot water 3 min may have influenced the rate of respiration and transpiration of the fruits, resulting in less loss. Guimarães et al. (2013) also found less weight loss in lychees treated with citric acid 3 and 6% regardless of the association with other treatments. A similar effect of citric acid on weight loss has been reported during the storage of cherimoya (Liu et al., 2016) and pitanga (Sanches et al., 2017). In 'Bengal' lychees, heating the fruits to 45ºC reduced the loss of weight during eight days of storage at 20ºC compared to the control (Matias et al., 2012).

Total Soluble solids

The content of soluble solids (SS) decreased over 12 days of storage (Fig. 2). The fruits of the control treatment showed a greater reduction at the end of the storage period (6.44 ± 0.77 ºBrix) about the initial day differing ($p<0.05$) from those treated with 3% citric acid and the combined effect of citric acid 3% + hot water 3 min whose reduction was 2.32 ± 0.93 and 1.68 ± 1.12 ºBrix, respectively.

According to Chitarra and Chitarra (2009), SS tends to increase with maturity due to the increase in the content of simple sugars. However, rambutan as a non-climacteric fruit (Mendoza et al., 1972) does not accumulate reserve carbohydrates and, therefore, an increase in the content of soluble solids after harvest is not common. As the main components of SS are sugars and these are used as substrates in respiration, justifying the decrease in content with the storage time. Other research also reports a decrease in SS contents during refrigerated storage (Setyadjit et al., 2018; Sanches et al., 2018) or under ambient conditions (Saowakon et al., 2017; Manjunath et al., 2018) of rambutan. Thus, the preservation of SS in fruits treated with 3% citric acid and its combination with hot water for 3 minutes in 12 days is indicative of their positive effect on respiratory metabolism when compared to control.

Titratable acidity

The titratable acidity (TA) of the fruits tended to decrease with the storage time. The mean values went from 0.27 ± 0.011 on day zero to 0.14 ± 0.008 g.100g^{-1} citric acid at 12 days. The combined treatment of citric acid 3% + hot water 3 min maintained greater stability of the content of organic acids up to nine days and, at 12 days the content did not differ from those treated only with citric acid 3%. Even so, the reduction in TA in the fruits of these treatments was less (about 0.08 ± 0.005 g.100g^{-1} citric acid) during the entire storage period when compared ($p<0.05$) to the fruits of the control treatment (0.18 ± 0.0010 g.100g^{-1} citric acid) (Fig. 3).

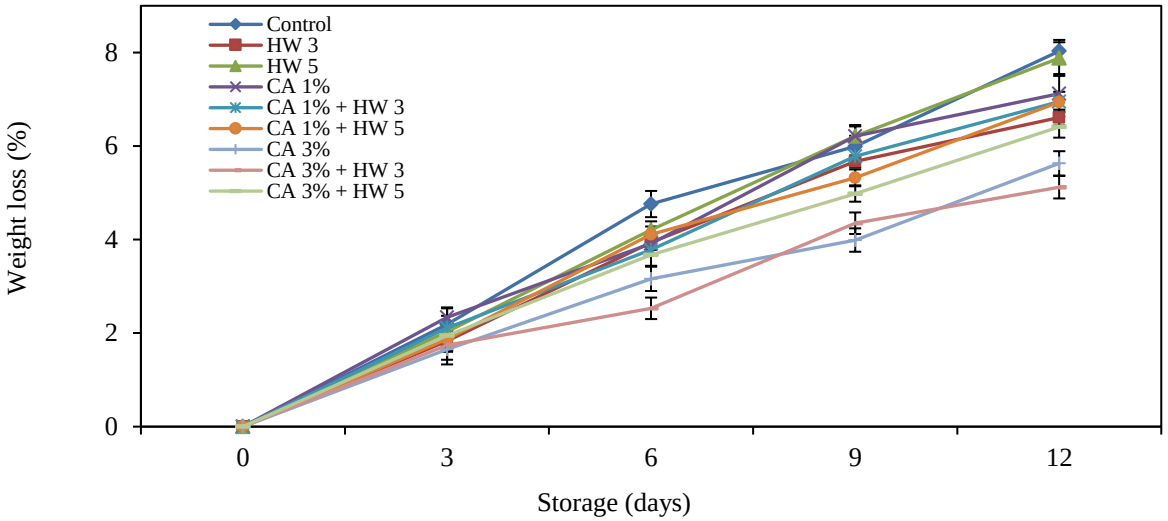

Fig. 1. Weight loss (%) in rambutan submitted to treatment with hot water and citric acid and stored under refrigeration (10 ± 1 ºC) for 12 days. The standard deviation indicates a significant difference ($p<0.05$).

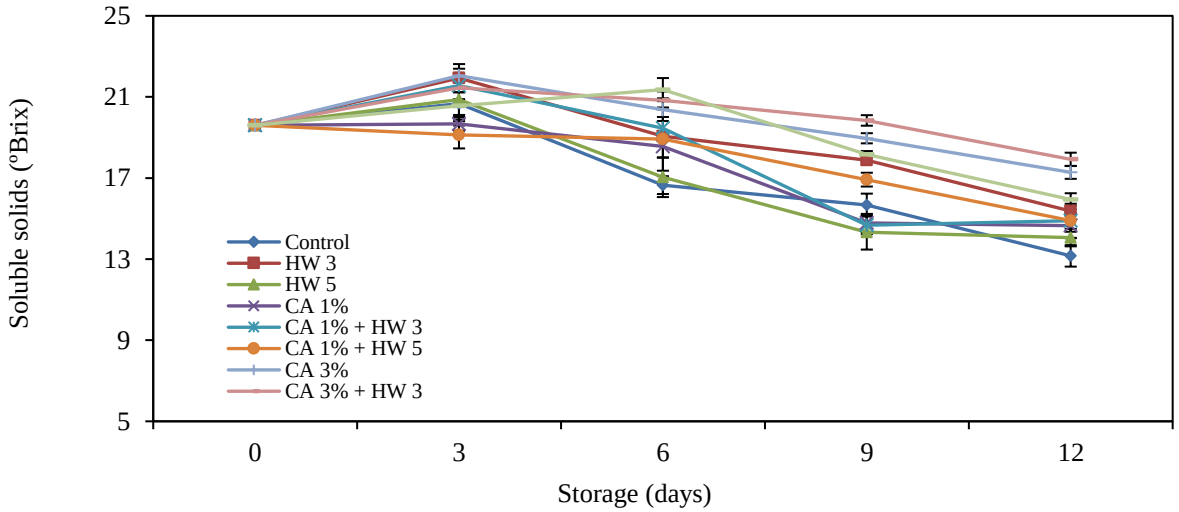

Fig. 2. Soluble solids (ºBrix) in rambutan submitted to treatment with hot water and citric acid and stored under refrigeration (10 ± 1 ºC) for 12 days. The standard deviation indicates a significant difference ($p<0.05$).

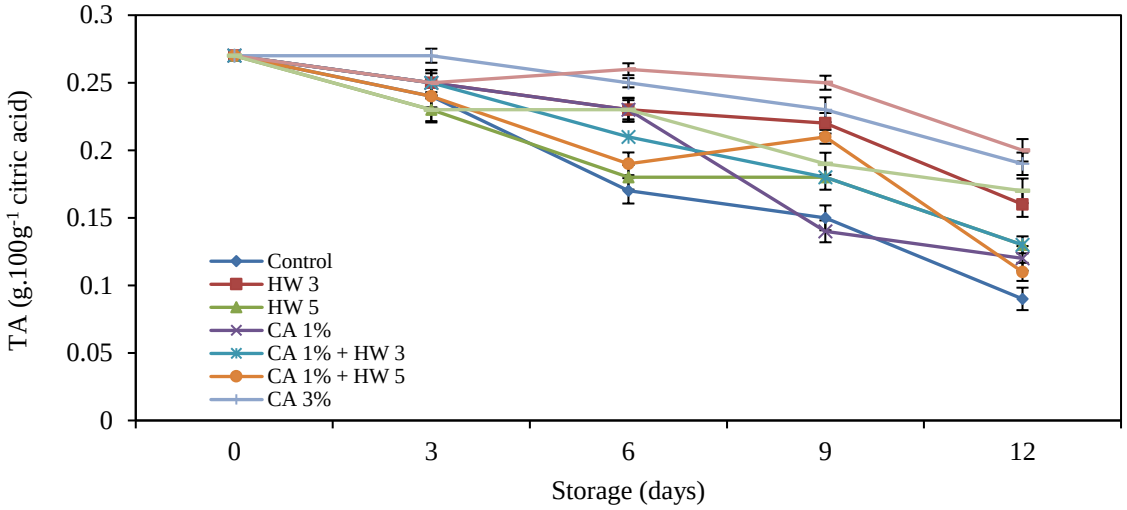

Fig. 3. Titratable acidity (g.100g-1 citric acid) in rambutan submitted to treatment with hot water and citric acid and stored under refrigeration (10 ± 1 ºC) for 12 days. The standard deviation indicates a significant difference ($p<0.05$).

The decrease in the levels of TA is the result of the natural process of fruit ripening, where the reduction in the content of organic acids results from its use in respiratory metabolism or conversion to sugars, as they are considered energy reserves (Chitarra & Chitarra, 2009). In this study, acidity reduced 0.13 g.100g^{-1} citric acid about the initial day of storage, similar to those obtained by Hafiz et al. (2017) who observed a reduction of 0.11 g.100g^{-1} citric acid in rambutan 'Anak Sekolah' during 20 days of storage at 10 ºC and 95% RH.

pH

For the pH, there was a significant effect ($p<0.05$) only about the days of storage characterized by an increase in values between day zero (3.41 ± 0.55) and the 12th day 4.56 ± 1.02) (Fig. 4).

Increases in the pH values of rambutan fruits were also obtained by Manjunath et al. (2018) during five days of storage at 30 ºC. Sanches et al. (2018) working with rambutan fruits in different packages and cold storage (10 ºC and 85% RH) observed that the initially low pH levels (3.29) tend to increase with the drying of the pericarp reaching 4.50 to 12 days. Damodaran et al. (2010) explained that the increase in pH values during storage is probably due to the beginning of the senescence processes through the respiratory process that consumes the organic acids in greater intensity, causing a decrease in acidity and, consequently, an evolution in fruit maturation.

Vitamin C

The decrease in the vitamin C content occurred in all treatments with the storage time, however, the fruits immersed in 3% citric acid + hot water 3 min maintained a higher content (40.34 ± 1.23 mg.100g^{-1} MF) relation to the others treatments ($p<0.05$) at the end of 12 days (Fig. 5). For the same period, untreated fruits (control) and when heated in water for 5 min exhibit the lowest contents (15.24 ± 1.07 and 17.56 ± 1.18 mg.100g^{-1} MF), respectively.

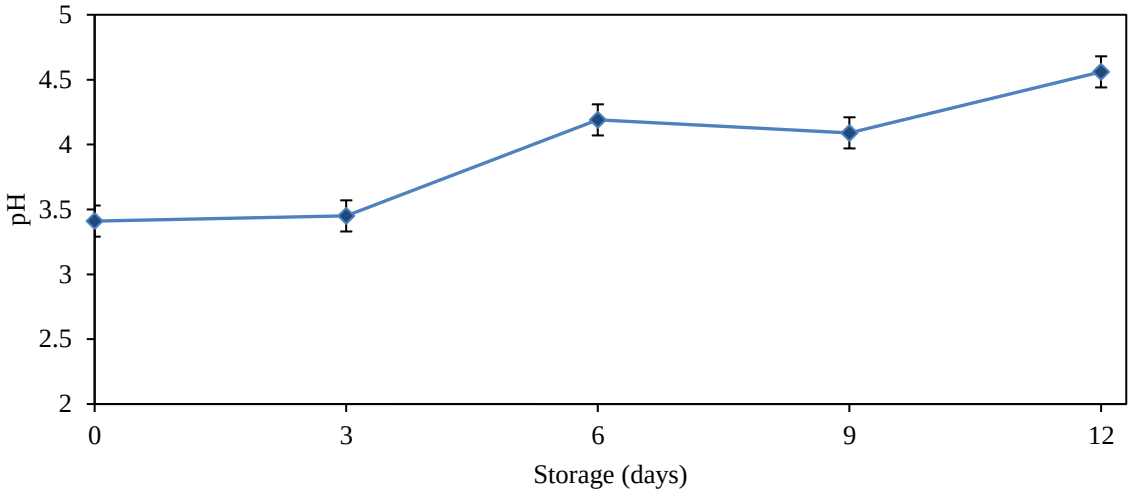

Fig. 4. pH in rambutan submitted to treatment with hot water and citric acid and stored under refrigeration (10 ± 1 ºC) for 12 days. The standard deviation indicates a significant difference ($p<0.05$).

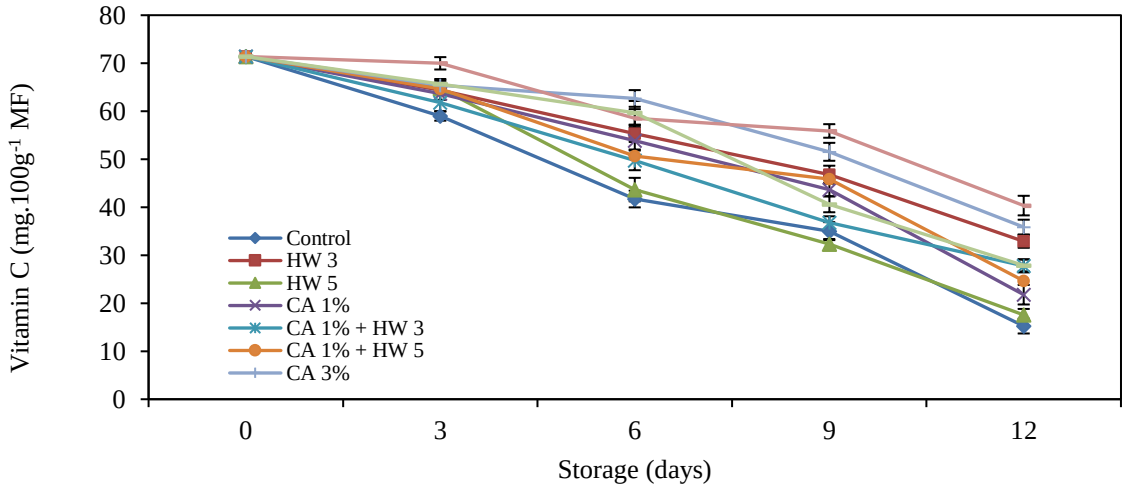

Fig. 5. Vitamin C (mg.100g-1 MF) in rambutan submitted to treatment with hot water and citric acid and stored under refrigeration (10 ± 1 ºC) for 12 days. The standard deviation indicates a significant difference ($p<0.05$).

Vitamin C content tends to decrease with ripening and storage of vegetables, due to the direct action of the enzyme ascorbic acid oxidase (Chitarra & Chitarra, 2005). In this study, the vitamin C content ranged from 71.23 to 15.24 mg.100g-1 MF over 12 days, similar values were reported by Sanches et al. (2018) in rambutan stored at 10 ºC for 16 days (79.4 to 28.3 mg.100g-1 MF) and by Arenas et al. (2012) whose content varied between 75.5 and 40.0 mg.100g-1 MF during 10 days of storage at 10 ºC. However, Manjunath et al. (2018) found values varying between 28.3 and 15.4 mg.100g-1 MF over 14 days at 10 ºC. For Mditshwa et al. (2018) factors such as genotype, cultivation conditions, water loss, temperature, and relative humidity of the storage environment and the postharvest conservation technology used directly influence the total and oxidized content of ascorbic acid in vegetables.

Browning pericarp and pulp

The combined treatment of citric acid 3% + hot water 3 min significantly inhibited ($p < 0.05$) the darkening of the fruit pericarp relation to the other treatments, being characterized with a score of 3.75 ± 0.31 (only 10% browning) after 12 days. In the fruits of the treatment control the score 3.0 limit for commercialization (25% of browning) was reached on the sixth day of storage and the score 1.0 ± 0.82 (100% browning) from the ninth day (Fig. 6A).

The pulp combined effect of 3% citric acid + hot water 3 min inhibited the browning until the sixth day of storage (note 5.0 ± 0.42), that is, without browning in comparison to the other treatments, mainly in the fruits of control treatment that were already characterized with a score of 3.25 ± 0.26 (10% browning) (Fig. 6B). At the end of storage, the combination of 3% citric acid + 3 min hot water and only 3% citric acid were characterized with an average score of 4.0 ± 0.16 (5% browning) differing ($p < 0.05$) from others, especially the control fruits (1.0 ± 0.21) with 50% dark pulp.

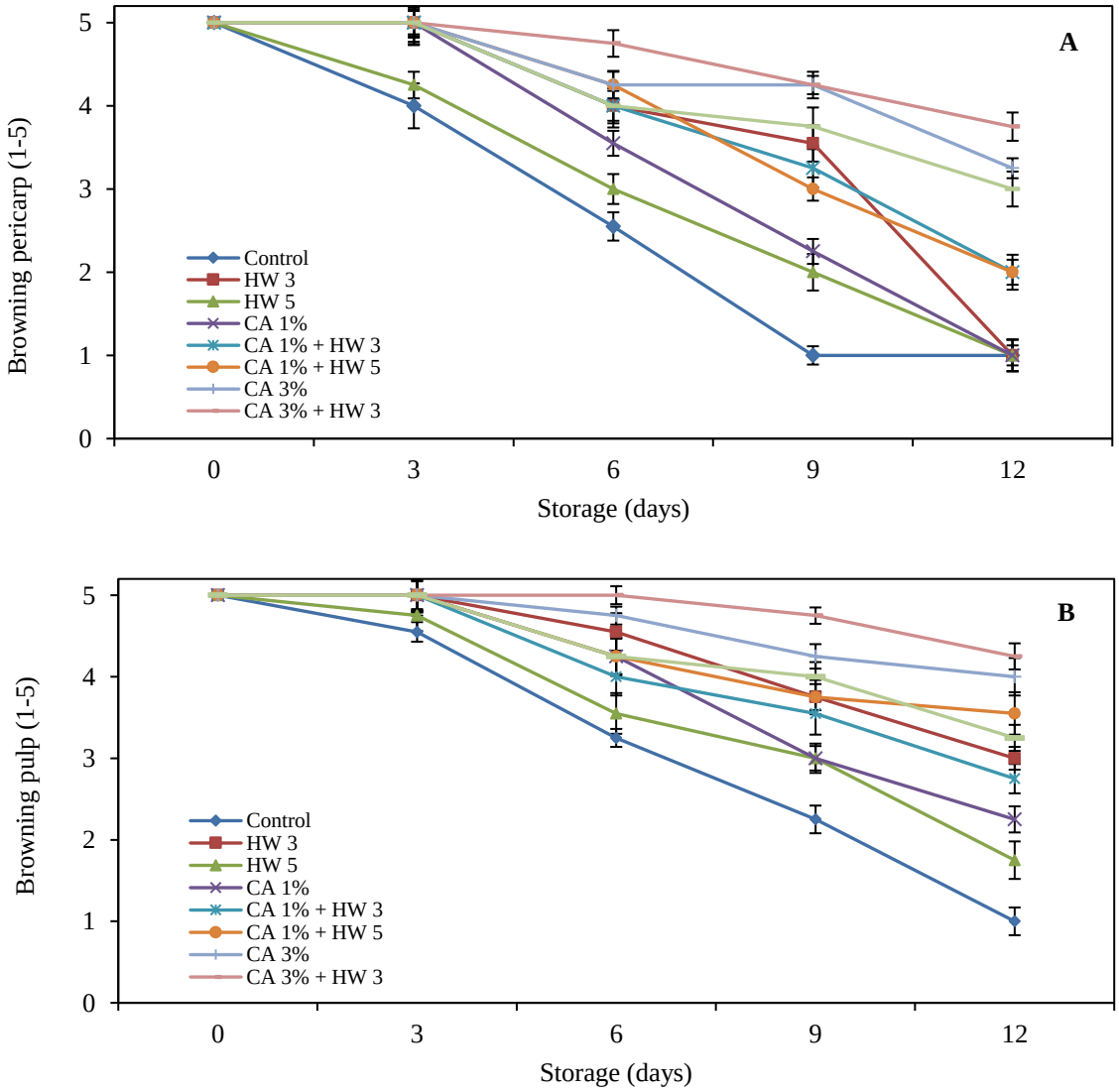

Fig. 6. Browning of the pericarp (A) and pulp (B) in rambutan subjected to treatment with hot water and citric acid and stored under refrigeration (10 ± 1 ºC) for 12 days. The standard deviation indicates a significant difference ($p<0.05$).

The browning of the pericarp and pulp of the rambutan is mainly associated with increased water loss due to respiration, perspiration of the fruits, and also to the enzymatic reaction (O'hare, 1995; Manjunath et al., 2018). In this way, the inhibition of browning in fruits treated with 3% citric acid + hot water 3 min is a direct result of weight loss (Figure 1) associated with delayed ripening (Fig. 2 and 3). In increase, the antioxidant role of citric acid in conjunction with heat (hot water) that inactivates browning promoting oxidase enzymes delayed the browning of the pericarp and pulp in this study. The storage of lychees 'Kwai' and 'Guiwei' at 0.4 ºC and 'Bengal' at 0.5 ºC treated with 6% citric acid maintained the reddish color and reduced the browning of the pericarp (Ducamp-Collin et al., 2008; Guimarães et al., 2013), respectively. The immersion of 'Bengal' lychees in hot water for 5 and 10 minutes at 45 ºC was efficient in maintaining the red color of the fruits, reducing the enzymatic activity without compromising the physical-chemical quality (Souza et al., 2010; Matias et al., 2012). According to Souza et al. (2010), the inadequate management of temperature in hydrothermal treatment can cause hyperthermic injury (collapse of the pulp, fruit without flavor, browning of the skin, production of ethanol and acetaldehyde). This justifies, for example, the greater darkening of the fruits when kept in hot water for five minutes.

CONCLUSION

The use of citric acid (3%), when combined with the heat treatment at 45ºC for 3 minutes, preserves the physical-chemical quality and alleviate the symptoms of browning of the pulp and rambutan pericarp stored in refrigeration (10ºC) for 12 days.

Hot water combined or not with citric acid for 5 minutes should be avoided, as it accelerates physiological processes related to ripening and induces the browning of the pericarp and pulp.

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Conflict of interest
The authors have no conflict of interest to report.

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