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Quality of mangabeira fruits from different maturation stages treated with $CaCl_2$

Qualidade de frutos de mangabeira de diferentes estágios de maturação tratados com $CaCl_2$

Calidad de la fruta de mangabeira de diferentes etapas de maduración tratados con $CaCl_2$

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Abstract
Hancornia speciosa is a fruit tree, popularly known as mangabeiras. The mangaba, fruits of this tree, are quite appreciated for their organoleptic characteristics. Because it is a climacteric fruit, this fruit has very high perishability. The use of products that extend the useful life is necessary. Calcium chloride ($CaCl_2$) has been shown to be an alternative in post-harvest because it promotes few changes in fruit quality and increases the storage period. Thus, the objective of this work was to evaluate quality attributes of mangaba fruits in two stages of maturation, 'Immature' and 'Mature', submitted to $CaCl_2$ application, in four storage times (0, 2, 4 and 6 days) under ambient atmosphere. During the experiment, the loss of fresh weight, color, pH, titratable acidity, soluble solids and SS/TA ratio were evaluated. It was verified that the 'mature' fruits showed a higher acidity and soluble solids content, even with the application of $CaCl_2$, the difference that the loss with the application of $CaCl_2$ was smaller. Unlike '‘Immature’ and ‘Immature’ fruits with $CaCl_2$ in which these characteristics were acquired as the experiment was conducted, in addition to presenting lower values for weight loss, pH and color.
Keywords: *Hancornia speciosa*; Post-harvest technology; Storage.

Resumo
Hancornia speciosa é uma árvore frutífera, popularmente conhecida como mangabeira. A mangaba, frutos dessa arvore, são bastante apreciados pelas suas características organolépticas. Por ser um fruto climatérico, esse fruto tem perecibilidade muito alta. O uso de produtos que prolonguem a vida útil se faz necessário. O cloreto de cálcio ($CaCl_2$) mostra ser uma alternativa na pós-colheita por promover poucas alterações na qualidade dos frutos e aumentar o período de armazenamento. Sendo assim, o objetivo deste trabalho foi avaliar atributos de qualidade de frutos de mangaba em dois estádios de maturação, ‘de vez’ e ‘de queda’, submetidos a aplicação de $CaCl_2$, em quatro tempos de armazenamento (0, 2, 4 e 6 dias) sob atmosfera ambiente. Durante a condução do experimento foram avaliados a perda de massa fresca, cor, pH, acidez titulável, sólidos solúveis e relação SS/TA. Foi verificado que os frutos ‘de queda’ apresentaram uma maior acidez e teor de sólidos solúveis, mesmo com a aplicação de $CaCl_2$, a diferença que a perda com a aplicação do $CaCl_2$ foi menor. Ao contrário dos frutos ‘de vez’ e ‘de vez’ com $CaCl_2$ em que estas características foram adquiridas conforme a condução do experimento, apresentando além disso, menores valores para perda de massa, pH e cor.
Palavras-chave: *Hancornia speciosa;* Tecnologia pós-colheita; Armazenamento.

Resumen
Hancornia speciosa es un árbol frutal, conocido popularmente como mangabeira. El mangaba, frutos de este árbol, son muy apreciada por sus características organolépticas. Debido a que es una fruta climatérica, esta fruta tiene una perecibilidad muy alta. Es necesario el uso de productos que prolonguen la vida útil. Se ha demostrado que el cloruro de calcio ($CaCl_2$) es una alternativa en poscosecha porque promueve pocos cambios en la calidad de la fruta y aumenta el período de almacenamiento. Así, el objetivo de este trabajo fue evaluar atributos de calidad de frutos de mangaba en dos etapas de maduración, “de vez” y “caer”, sometidos a aplicación de $CaCl_2$, en cuatro tiempos de almacenamiento (0, 2, 4 y 6 días) en atmósfera ambiente. Durante el experimento se evaluó la pérdida de peso fresco, color, pH, acidez titulable, sólidos solubles y relación SS/TA. Se verificó que los frutos 'caídos' mostraron mayor acidez y contenido de sólidos solubles, aún con la aplicación de $CaCl_2$, la diferencia que la pérdida con la aplicación

de $CaCl_2$ fue menor. A diferencia de los frutos "de vez" y "de vez" con $CaCl_2$ en los que estas características se adquirieron a medida que se realizaba el experimento, además de presentar valores más bajos de pérdida de peso, pH y color.
Palabras clave: *Hancornia speciosa;* Tecnología poscosecha; Almacenamiento.

1. Introduction

The mangabeira (*Hancornia speciosa* GOMES) is a fruit native to Brazil, belonging to the Apocynaceae family. This species is found naturally in the cerrado biome of the midwest and southeast regions, and in the Northeast region it is widely found in coastal plateaus and coastal lowlands. (Lédo et al., 2007; Martins et al., 2012). The state of Sergipe is the largest producer of mangaba fruit (33%), followed by Rio Grande do Norte (27%), Paraíba (20%), Bahia (13%), Alagoas (5%), Minas Gerais, Maranhão, Ceará and Goias (1%) (Conab, 2017). Agroextractivism is the main form of extraction of this fruit, however, with the growth of the real estate sector, shrimp farming and coconut monocultures this activity has reduced over the years (Mota, Schmitz & Silva Júnior, 2015).

Appreciated for their physical characteristics, aroma and flavor, the mangabeira fruits have high nutritional value, good digestibility, high content of vitamin C, iron and proteins, these contents being higher in comparison to other fruits such as orange (Lima et al., 2015a; Rufino et al., 2010; Santos et al., 2012). Mangabas are used by the food industry in the form of pulp, cocktails, candy in syrup, jellies, ice cream, liqueurs, vinegars, wines, syrups and jams. However, fresh consumption is still the main form of use of mangaba (Campos et al., 2011; Carnelossi et al., 2009; Clerici & Carvalho-Silva, 2011).

When harvested at the stage of physiological maturity or “Immature” the mangabas have a yellow-green hue, while the fruits that come off the plant and are found in the soil, called “Mature” fruits, have a light yellow hue. Among consumers, mature fruits are more widely accepted when compared to immature, however, due to their rapid deterioration, the reuse of the remaining fruits cannot be carried out by traders. This is due to the fact that mangaba fruits, due to their climacteric breathing pattern, are highly perishable, limiting fresh trade to open markets and roads close to extractive areas. (Lima & Scariot, 2010).

The post-harvest quality of the fruits is related to the reduction of the deterioration rate of these fruits, maintaining parameters that are attractive to the consumer, such as firmness, color and appearance. This quality can be measured through attributes such as: loss of fresh weight, pH, titratable acidity, soluble solids, color, among others (Chitarra & Chitarra, 2005).

To increase the durability of the fruits, minimizing losses in the post-harvest process, conservation techniques are employed. The use of chemical preservatives such as ascorbic acid, calcium chloride, L-cysteine and 1-methylcyclopropene are widely used to maintain the quality of fruits and vegetables (Ali et al., 2013; Li et al., 2014; Vilas Boas, Reis & Melo, 2009). Among these preservatives, calcium chloride has shown some effects when applied by immersion in fruits and vegetables (Melo & Vilas-Boas, 2007). These effects are associated with the role of calcium in the regulation of softening of the fruits forming bridges between pectic acids and polysaccharides (Mota et al., 2002; Werner et al., 2009), giving resistance to these (Luna-Guzman et al., 1999; Lara et al., 2004).

For a fruit to reach other markets, it is necessary to evaluate techniques that provide conservation and added value to it. The use of post-harvest technologies, such as the use of calcium chloride, can increase the fruit production chain, extending the useful life and enabling transport to markets more distant from the harvesting sites. (Santos et al., 2009). Thus, the objective of this work was to evaluate attributes of post-harvest quality in mangaba fruits immature and mature treated with calcium chloride by immersion.

2. Methodology

In this experiment, mangabeira fruits from an orchard in the municipality of Barra dos Coqueiros - Sergipe were used (10°54'32"S e 37°02'19"W). At the time of harvest, the fruits harvested from the mangaba tree near the maturation point referenced by the waste pickers were defined as immature and mature those on the ground, according Vieira Neto (2002). After collection, the fruits were taken to the Ecophysiology and Post-harvest laboratory (ECOPOC) of the Department of Agronomic Engineering at the Federal University of Sergipe (UFS), São Cristóvão, Sergipe. Subsequently, these fruits were washed in running water for 1 minute, followed by washing in distilled water. Then, they were kept in drying trays with the aid of paper towels.

In $CaCl_2$ treatments, the fruits were immersed in a 3% calcium chloride solution for 5 minutes, and for the control group, only the solvent (distilled water). Subsequently, the fruits were placed on a PVC type plastic tray. Afterwards, they were stored in an ambient atmosphere at 23 ± 2 ° C and relative humidity of 75 ± 2%, being used in the experiment only uniform fruits and with no injuries.

Each experimental plot was composed of 3 fruits that were weighed using a semi-analytical balance (Gehaka, BG 8000) at the beginning of the experiment and later in each sampling period (2, 4, and 6 days) the weighing was performed to quantify the accumulated weight loss, expressed as a percentage of lost fresh weight. This calculation was made through the difference between the initial mass of the fruit and the final mass.

For color measurements, a portable colorimeter model CR-400 (Konica Minolta, Osaka, Japan) was used. The measurements were made at 3 points equidistant from the medial region of the fruit. The variables luminosity (L*), chromaticity (C*) and angle Hue (H*) were recorded.

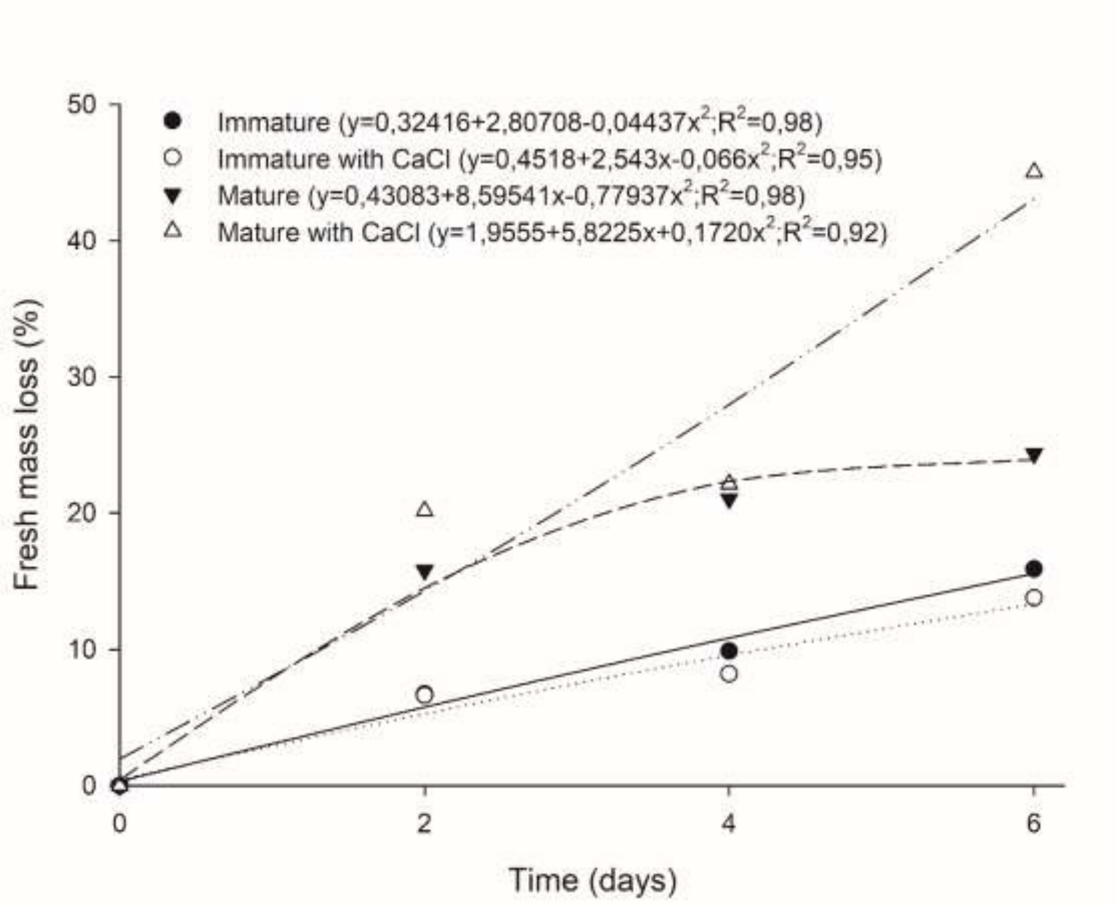
The content of soluble solids (SS) was determined in a portable refractometer RTD-45 (Instrutherm, São Paulo, Brazil) and expressed in °Brix. The pH was evaluated by weighing 10g of each fruit, macerating it and diluting it in 100ml of distilled water, determining its value through the pHS-3E bench pH meter (LabMeter, São Paulo, Brazil). The total acidity (TA) was determined by removing 25 ml of the solution used to determine the pH, using 0.1N molarity NaOH and 1% phenolphthalein as an indicator and the result was expressed in % citric acid. The SS/TA ratio was obtained by dividing the parameters. The determination of these physical chemical properties was carried out according to Carnelossi et al. (2004).

The experiment was carried out in a completely randomized design with a factorial arrangement (4x4) with three replicates per treatment / evaluation, each repetition consisting of a fruit. The arrangements corresponded to the four treatments used (immature and mature treated and not treated with calcium chloride) and four evaluation times (0, 2, 4 and 6 days). The data obtained were submitted to analysis of variance (ANOVA), by the program R (Bhering, 2017; R Core Team, 2018), and submitted to the Tukey test, at 5% probability ($P \leq 0.05$) for comparison of means. For the loss of fresh mass and color, polynomial regression analysis was performed. The graphics were plotted using SigmaPlot 12.5 software (Systat software, San Jose, CA, USA).

3. Results and Discussion

The loss of fresh mass of the immature and mature mangaba fruits with and without calcium chloride application are shown in Figure 1. For all treatments, the loss of mass increased over time. However, it is possible to note that for immature fruits, this increase is smaller when compared to mature fruits. It is also worth noting that the fruits immature with the application of $CaCl_2$, the loss of fresh weight was lower when compared to fruits without treatment.

Figure 1: Loss of fresh mass in mangaba (*Hancornia speciosa*) fruits of different ripening stages (immature and mature), without and with application of calcium chloride ($CaCl_2$) at ambient temperature (25 ° C ± 3 ° C; UR 75 % ± 10%) during storage (6 days).



Source: Authors.

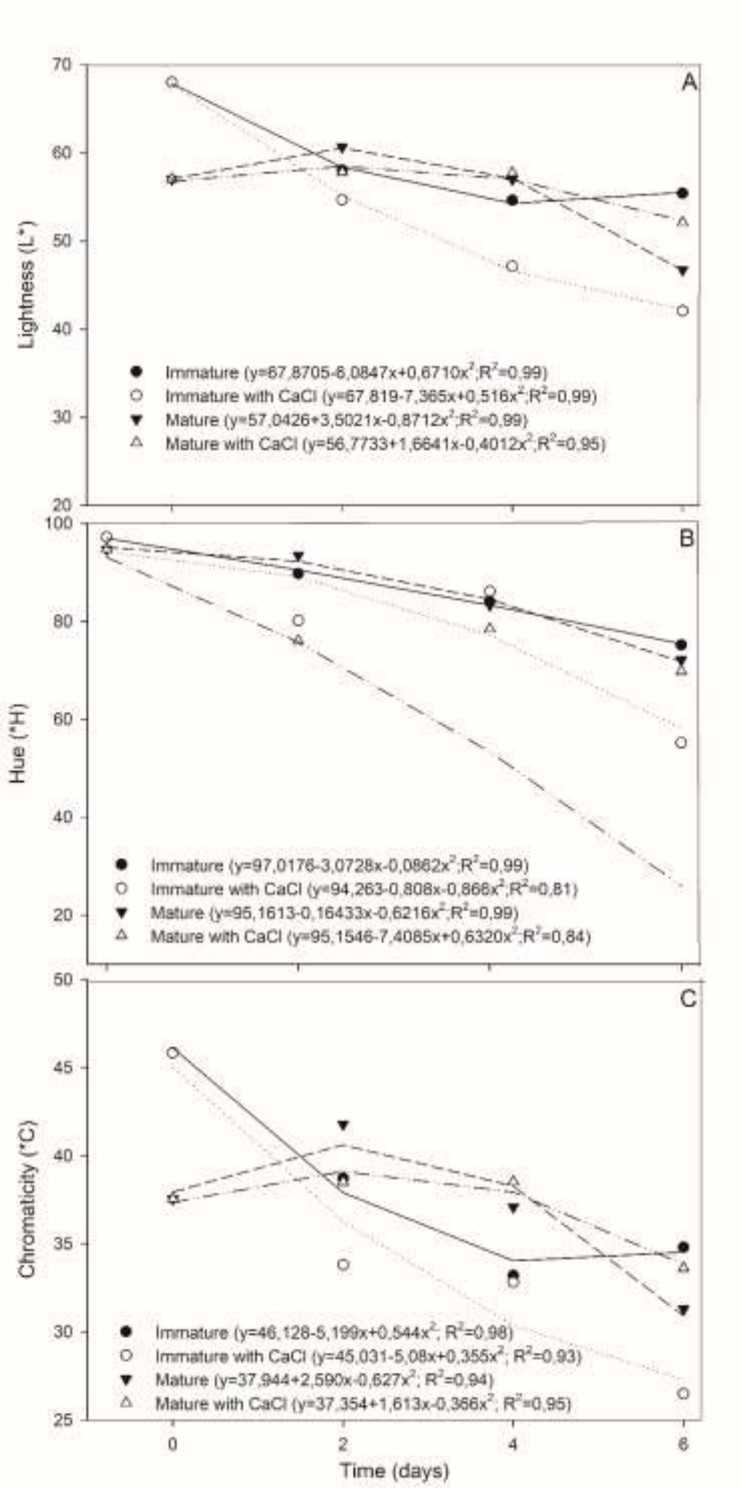
Loss of fresh weight is a limiting factor in fruit conservation (Santos et al., 2008), which implies in the logistics between harvest time and commercialization of mangaba. Carnelossi et al., (2004), states that mature mangaba fruits become deteriorated after 3 and 7 days of storage under temperatures of 25º and 18º C, thus demonstrating the importance of harvesting immature fruits. In the present work, the mature fruits were deteriorated on the sixth day of evaluation, thus limiting the continuity of the evaluation of the experiment.

One possibility for this greater loss of fresh mass in mature mangaba is due to the occurrence of unwanted cellular changes. This result may be associated with water loss due to fruit transpiration, resulting in softening during storage (Khaliq et al., 2015).

The results obtained for skin color in the parameters of luminosity (L), Chromaticity (C) and Hue angle (H), are represented in figure 2. The fruits immature showed higher luminosity (figure 2A) during the first evaluation, however, the fruits mature and immature were practically the same in the other evaluation days. The exception was the immature treatment with $CaCl_2$, which had the lowest luminosity values from the second day of storage. This behavior was similar in the chromaticity parameter (*C).

A reduction in the Hue angle (*H) was observed for all treatments, with lower values for $CaCl_2$ treatments (figure 2B). This suggests that the ripe fruits look greenish yellow and turn reddish yellow when ripe.

Figure 2: Peel color of mangaba fruits (*Hancornia speciosa*) from different ripening stages (immature and mature), without and with application of calcium chloride ($CaCl_2$) at ambient temperature (25 ° C ± 3 ° C; UR 75% ± 10%) during storage (6 days).



Source: Authors.

For chromaticity (*C) (figure 2C), this behavior was similar to that of luminosity (figure 2A), with the superiority of the fruit immature was maintained, while the immature treatment with $CaCl_2$ was the lowest. This means that in the treatment of the fruit immature with $CaCl_2$ the color was maintained throughout storage. The loss of green color in mature and immature fruits without the application of $CaCl_2$ is due to the decomposition of the chlorophyll pigment, where several factors act on it. Thus, the breakdown of this pigment occurs from the accumulation of organic acids and other compounds in the vacuole, which activate the chlorophyllase enzyme and the oxidizing systems that degrade them (kaewsuksaeng, 2011). The change in the color change of the fruit skin from light green to yellow with spots is indicative of chlorophyll degradation, and this process is associated with the climacteric, being more intense between the pre-climacteric and the maximum (peak) climacteric (Paul, Pandey & Srivastava, 2012). That is, the degradation of traces of chlorophyll and slight degradation of yellow pigments, most likely carotenoids, and synthesis of red pigments (Lima et al., 2015b) In this work it was observed that the mature fruits already had a light yellow color indicating the proximity of the climacteric peak. Since, for the fruit immature, this color was acquired during the evaluation. The rapid increase in browning density was probably favored by the action of the enzyme polyphenol oxidase in the presence of high oxygen content (Palou et al., 1999).

The color change in the fruit peel that allows the appearance of the typical color of any analyzed species is an important indicator of the stage of fruit ripening, for which it is important to evaluate the yellowing of the peel or greening index (Chitarra & Chitarra, 2005).

Considering the pH (Table 1), in relation to the comparison between treatments, it is observed that on the second day the mature treatment with $CaCl_2$ was the least acidic. From the fourth day of storage, it was observed that the immature treatment with $CaCl_2$ was the least acidic. When taking into account the comparison of the same treatment over time, in the mature fruits, a reduction in pH was observed, increasing the acidity. While, for the immature fruits, this variation was smaller. The titratable acidity (TA) was variable between treatments and over time (Table1). The immature fruits showed their highest value only on the last day of evaluation (day 6). When $CaCl_2$ was applied, the highest % of citric acid was anticipated for day 2 of evaluation. Regarding the mature treatment, their highest TA values were observed on day 4 of the evaluation, mainly for the mature treatment with $CaCl_2$.

Table 1: pH, titratable acidity (% citric acid), total soluble solids content (°BRIX) and ratio of soluble solids by titratable acidity ($SS.TA^{-1}$) in mangabas treatments without and with $CaCl_2$ stored at ambient temperature (25°C ± 2°C) and relative humidity (75% ± 5%).

Treatments	**Storage time (days)**			
	0	**2**	**4**	**6**
	pH			
Immature	3.29±0.04aA	2.90±0.02bB	3.18±0.03aA	2.99±0.02bB
Immature with $CaCl_2$	3.29±0.04aA	2.87±0.03bB	3.17±0.02aA	3.20±0.04aA
Mature	3.34±0.04aA	3.09±0.04aB	3.07±0.05abB	3.04±0.04bB
Mature with $CaCl_2$	3.34±0.05aA	3.00±0.03abB	2.93±0.05bB	3.04±0.05abB
	Titratable acidity (% citric acid)			
Immature	1.60±0.03bD	2.20±0.03bcB	1.83±0.04cC	2.47±0.04aA
Immature with $CaCl_2$	1.60±0.03bB	2.87±0.03aA	1.60±0.03dB	1.67±0.02cB
Mature	2.23±0.03aA	2.07±0.04cB	2.30±0.05bA	2.23±0.04bA
Mature with $CaCl_2$	2.23±0.04aBC	2.30±0.06bB	2.63±0.04aA	2.10±0.05bC
	Soluble solids (°BRIX)			
Immature	15.70±0.20bB	35.40±3.22aA	12.40±1.04aB	15.60±0.61aB
Immature with $CaCl_2$	15.70±0.20bA	15.73±0.62bA	14.27±1.27aA	14.13±0.62aA
Mature	26.87±4.47aA	14.73±1.66bB	12.13±1.37aB	13.27±1.72aB
Mature with $CaCl_2$	26.87±4.98aA	11.60±0.91bB	13.77±1.21aB	15.23±1.57aB
	$SS.TA^{-1}$			
Immature	9.82±0.29aB	16.12±1.60aA	6.76±0.50abB	6.33±0.27aB
Immature with $CaCl_2$	9.82±0.29aA	5.49±0.25bB	8.95±0.96aAB	8.48±0.40aAB
Mature	11.98±1.79aA	7.12±0.76bB	5.27±0.56bB	5.97±0.87aB
Mature with $CaCl_2$	11.97±2.02aA	5.04±0.33bB	5.22±0.41bB	7.31±0.95aB

The means followed by the same lowercase letter in the column and uppercase in the row do not differ significantly from each other by the Tukey test ($p \leq 0.05$). The averages are presented with their standard deviations. Source: Authors.

The greatest variation for mature fruits is due to rapid ripening after maturation (12-24 hours). According to Silva et al. (2013), the increase in the storage time increases the acidity content of the mangabeira fruit regardless of the stage of maturation, this being evidenced from the second day of storage. However, for fall fruits this increase was higher. The greatest elevation of acids for falling fruits is that these fruits only detach from the plant, when they complete maturation (Vieira Neto, 1997). Since, the acidity does not decline in these fruits during ripening, but after ripening this characteristic is observed due to the use of sugars (soluble solids) as a source of energy for metabolic processes, with a greater release of H^+ in the middle.

The content of soluble solids (Table 1) varied between treatments. The fruits immature showed a variation of 12-35 ºBrix. When $CaCl_2$ was applied (immature with $CaCl_2$), this variation was much smaller, at 14-16 ºBrix. For mature fruits, this variation was 12-27 ºBrix, throughout the study, while for mature fruits with $CaCl_2$, the variation was 11-27 ºBrix. The variation in the concentration of reducing and non-reducing sugars was possibly responsible for these oscillations, since reducing sugars increase with advancing maturation (Chitarra & Chitarra, 2005). Carnelossi et al., (2004) observed that falling fruits have a greater accumulation of soluble solids due to the loss of water from the fruit during storage.

A gradual drop in the $SS.TA^{-1}$ ratio was observed for treatments without $CaCl_2$ application (Table 1). The treatments immature and mature in which $CaCl_2$ was applied, this fall in the $SS.TA^{-1}$ ratio was less. The $SS.TA^{-1}$ ratio is indicative of palatability. It is usually used to assess the degree of ripeness of the fruit, as well as its flavor, which is mainly represented by the sweetness / acidity balance, acceptable to the human palate. (Soares Junior et al., 2008). This relationship shows the mature fruits had a more acidic taste, while the immature fruits had a less acidic to mild flavor. The pH and TA values suggest fruits with substantial acidity, although this acidity is in contrast to the high sweetness indicated by the high values of soluble solids.

4. Conclusion

Mature fruits have better quality attributes while retaining their organoleptic characteristics for up to six days, however, they are more perishable when compared to immature fruits. When the $CaCl_2$ treatment is applied to both immature and mature fruits, less organoleptic losses are noted, as well as storage time.

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