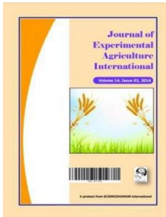

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Modified Atmosphere and Refrigeration in Postharvest Conservation of Atemoya cv. Gefner

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The objective of this study was to evaluate the effect of the modified atmosphere under refrigeration for 28 days in the Atemoya Gefner.
Study Design: Experiment 1 and 2 was installed in a completely randomized design, in a factorial 1x4 and 2x8, respectively.
Place and Duration of Study: The experiment was conducted in a cold chamber at the State University of Montes Claros, Brazil, between July and August 2018.
Methodology: In the first, the percentage of fruits that presented cold injury (CI) in unpackaged fruits and stored at 15°C for six days was visually evaluated. In the second experiment two pack were used and stored at 15°C and evaluated the physical and chemical characteristics.
Results: In the first experiment, from the 2nd day 100% of the fruits showed CI that progressed to

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stage 3 on the 6th day of storage. This result justifies the need to store the atemoya under modified atmosphere under 15°C for 28 days. It was found at the end of 28 days, experiment two, that the packages 1 and 2 showed quality fruits, with characteristics of ripe fruits, with 22 °Brix average values, reduced titrable acidity, light green color peel and good lightness. The pack1 showed better weight maintenance, with 1.54% of fresh weight loss against 2.36% for pack2.

Conclusion: There was a higher solubilization of total sugars and non-reducing sugars in pack1, being this the most indicated for atemoya fruits grown in northern Minas Gerais.

Keywords: A. squamosa L. x A. cherimola Mill.; package; "chilling"; annonaceae.

1. INTRODUCTION

Brazil has favorable conditions for the cultivation of several fruit trees, and among them there is atemoya (*Annona squamosa* x *Annona cherimola*), a hybrid fruit belonging to the family Annonaceae, originating from the crossing between a tropical fruit, the sugar apple (*A. squamosa*), and a subtropical fruit, cherimolia (*A. cherimola*) [1].

Brazil's atemoya yield is mainly absorbed by the domestic market and sells at excellent prices due to its high quality and short supply.

However, the commercialization of atemoya is restricted to the domestic market, mainly because this fruit has a low post-harvest life, attributed to its high perishability [2]. This feature can be further aggravated when these fruits are harmed during harvesting, transport, handling and when stored for long periods, representing an obstacle to the maintenance of their quality. Some physical alterations, such as the rapid loss of firmness and changes in coloration due to the natural maturation process, are factors observed by consumers [3] and who depreciate the fruits [4,5].

One of the most effective and practical methods for prolonging shelf life of fresh fruits is refrigerated storage [6,7], because it maintains a low production of ethylene [8], delaying ripening, prolonging the shelf life and the period of commercialization [7]. Products that are derived from parents of tropical climate, under prolonged refrigerated storage present visible symptoms of cold disorders, the chilling [7], which makes it difficult or even impossible to send the fruits to the most distant consumer centers [9]. The symptoms of chilling in the anonaceous are browning of the peel and pulp, blockage of ripening [10] and loss of aroma and taste.

Another technique also used to prolong the post-harvest life of the fruits is the modified atmosphere [11]. The use of plastic films involving fruits provides maintaining relative humidity inside the package, reducing fruit mass losses, respiratory rates, ethylene production and reducing the incidence of chilling [12,13].

Normal maturation of the atemoya would occur at approximately 20°C and 85-95% RU, storage at 15°C and 85-90% RU [14,15] is recommended. It is necessary to define techniques of conservation that prolong the life postharvest and avoid the injury by the cold[5]. Technologies such as refrigeration and controlled atmosphere would help producers to achieve better conditions and competitiveness in the national and international markets [16].

The objective was to evaluate the effect of passive modified atmosphere using two packages that differ in density, keeping under refrigeration for 28 days atemoya fruits, cv. Gefner, grown in northern Minas Gerais.

2. MATERIALS AND METHODS

Atemoyas originated from a commercial orchard in the city of Matias Cardoso (latitude 15°0.2'52"S, longitude 43°50'3"W) in northern Minas Gerais, were hand harvested on the morning of March 15, 2013, at the physiological maturity stage (removal of carpels and slightly yellowish green color) and individually wrapped. Next, they were transported to the Laboratory of Postharvest Physiology of Fruits at the State University of Montes Claros, where they were selected, washed with detergent, rinsed in tap water, immersed for five minutes in an antifungal solution and air-dried. The research was conducted in two experiments:

Experiment 1: It corresponds to the witness, fruits without packaging. The fruits were placed in an expanded polystyrene tray. The experiment was carried out in a completely randomized design, and the evaluations were carried out in 4 evaluation periods (days 0, 2, 4 and 6) and 1 storage temperature (15 ± 1°C) with four replicates and four fruits per experimental unit.

The fruits were kept under refrigeration in a cold room at 15 ± 1°C and 85 ± 5% RH for 06 days (Fig. 1). The exposure time of 6 days was used based on the pre-experiment performed to determine maximum period when the symptoms of cold damage occur (of chilling injury). Experiment 1 evaluated visual estimation of chilling injury (CI), performed by a semi trained evaluator through the scale: 0 = absence of spots and stains on the peel, 1 = small brown spots, 2 = small brown stains, 3 = darker and larger stains. Results expressed as percentage.

Experiment 2: Randomly packed fruits (four per package), removing excess air from inside and tying, all manual process. Two packages corresponding to modified atmosphere (PACK1 and PACK2) were evaluated in eight periods (days 0, 4, 8, 12, 16, 20, 24 and 28), being the four experimental units composed of four fruits each. These packages were kept in cold storage for 28 days at 15 ± 1°C and 85 + 5% RH. The experiment was installed in a completely randomized design, in a 2x8 factorial.

The packages (Vegetal Pack Electropolímeros do Brasil) are produced in "zeolite" technology (polyolefins - zeolite nano particles), with a 25 microns thickness and different densities. The PACK1 presents a density of 0.9987 g cm^{-3} and PACK2 1.094 g cm^{-3}.

The following variables were evaluated in experiment 2: loss of fresh matter, evaluated by weighing the fruits, taking the initial weight of each sample and expressing the results as percentages; firmness measured in the center of the fruit, using digital texturometer, 4mm tip penetrating 15 mm to 1.50 mm s^{-1} with initial force of 25g and results in N. Soluble solids (SS) were determined using a digital refractometer (0 to 95 °Brix). The pH was measured using a pH meter. Titratable acidity (TA) was determined by titration, according to the AOAC [17], with results expressed as citric acid g 100 mL^{-1} of juice. Peel color analysis was carried out by directly measuring the reflectance of the L* (lightness), a* and b* coordinates. The values of a* and b* was converted into hue angle (h°= actg (a*/b*)(-1)+92 for a* negative and h°= 90-(actg (a*/b*)) for a* positive) and chroma saturation index($C^*= \sqrt{(a^*)^2+(b^*)^2}$). Starch and reducing sugar were determined using a spectrophotometer set to 510 nm, according to the method described by Nelson [18]. Total sugars were determined using a spectrophotometer set at 620 nm, according to the method described by Dische [19]. Non-reducing sugars were obtained by the difference of total sugars and reducing sugars (% non-reducing sugars = (total sugar - Sugar reducer) x (0.95)).

Results of the experiment 2 were subjected to analysis of variance, being the quantitative factors means, when significant, adjusted in regression equations. The means of the qualitative factors were compared by Tukey test at 5% significance, in isolated effect, and using the LSD (least significant difference) at 5% significance in interactions. Data were analyzed using the SAEG V 9.1 statistical software.

3. RESULTS AND DISCUSSION

In experiment 1, at day 2 100% of the fruits were on stage 1 of CI, with spots observed in the region between the carpels (Fig. 1). Progressively, the intensification of symptoms was occurring as the exposure time increased. On the 4th day, all fruits were characterized in stage 2 of CI. On the sixth day, all fruits expressed stage 3, with dark spots at the ends of carpels, large stains with maps delineation and depressions formed on the surface.

The CI is the physiological dysfunction, "chilling", which occurred due to the time the fruits were exposed to low temperature and the absence of packaging. This result justifies the need of the modified atmosphere to store atemoya fruits under 15°C for 28 days.

In the experiment 2, there was a significant effect of packaging for the variables loss of fresh mass, pH, titratable acidity, total sugar and non-reducing sugars. For the storage period there was significant effect for all variables. The interaction packaging * storage period was significant for the variables loss of fresh mass, titratable acidity, brightness, chromaticity, total sugar and non-reducing sugars.

The loss of fresh mass occurred progressively throughout the storage period (Fig. 2). The LSD occurred on the twelfth day, and the PACK1 presented desirable result superior to PACK 2. At the end, the PACK1 and PACK2 showed, respectively, 1.54% and 2.36% of losses. The lower density of PACK1 may have favored the lower exchange of water vapor and the consequent lower transpiration rate. This study found results comparable to other research relating to the same cultivar. Silva et al. [20] observed loss of 7.8% in unpackaged fruits and 2.5% in individually wrapped fruits with PVC film (polyvinyl chloride) for 15 days at 15°C. After nine days at 27°C and 85% RH, unpackaged, there was a loss of 17.11% of fresh mass and the fruits set became unsuitable for consumption [21]. The studies demonstrate the action of the modified atmosphere in preserving fresh mass, favoring the appearance, texture and weight (value) in the commercialization of the fruit.

During the evaluation period occurred a decrease in peel firmness, in both packages, being pronounced on the 24th day (Fig. 3). Initially, the fruits showed values above 60N, and finished with figures of about 15N. Atemoyas cv. African Pride, unpackaged, after 15 days at 14.5°C showed firmness of 10N [22]. The application of 1-MCP (1-methylcyclopropene) for 8 hours in the concentration 600 nL L^{-1} retarded the maturation by reducing loss of firmness of the sugar apple [23] and atemoyas cv. Gefner [24,25]. Sugar apple stored at 15°C for 21 days had a loss of firmness twice as fast as those untreated with 1-MCP [23], while in the atemoyas the loss of firmness was nine times smaller at 25 days at 15°C, compared to the untreated ones [25]. When associated 1-MCP and modified atmosphere (film of low density polyethylene, LDPE, of 16 μm) atemoyas maintained firmness four times greater at 20 days at 15°C [24].

There was a progressive linear increase in the levels of SS, with no significant difference between the packages (Fig. 4). There was an increase in the levels of SS on days 16 and 28, with mean values of 20 to 22 °Brix for PACK1 and PACK2 fruits, respectively. SS values of this work are within the range studied by Nietsche [26] in the northern region of Minas Gerais, who observed above 20 °Brix, with averages of up to 26 °Brix. Atemoyas cv. Gefner, with no packaging, stored at 15 °C had contents of 10 to 31.2 °Brix at the 15th day [20]. However, they showed twice the fresh mass loss of the present experiment, which may have contributed to higher concentration of SS.

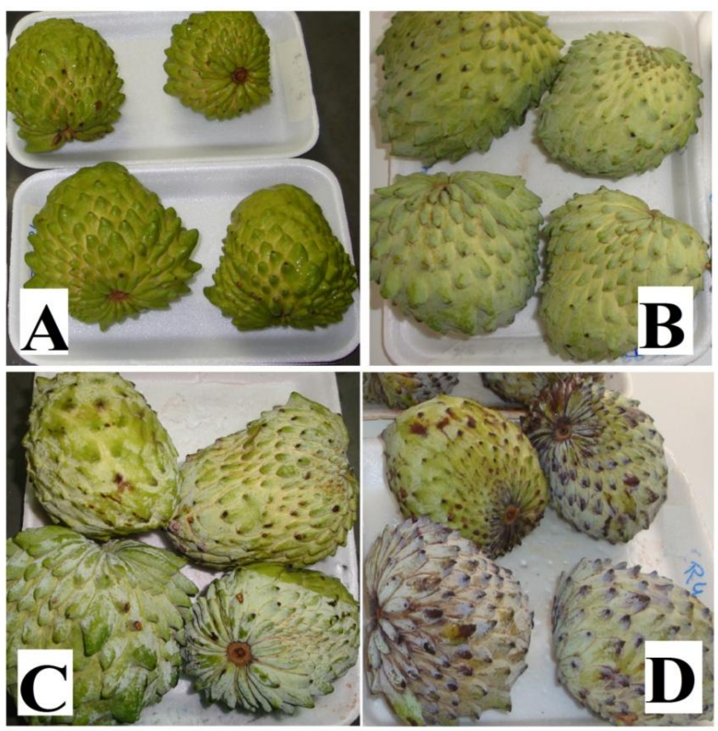

Fig. 1. Unpackaged atemoya stored for zero days (A), two days (B), four days (C) and six days (D) under refrigeration in a cold room at 15 ± 1°C and 85 ± 5% RH

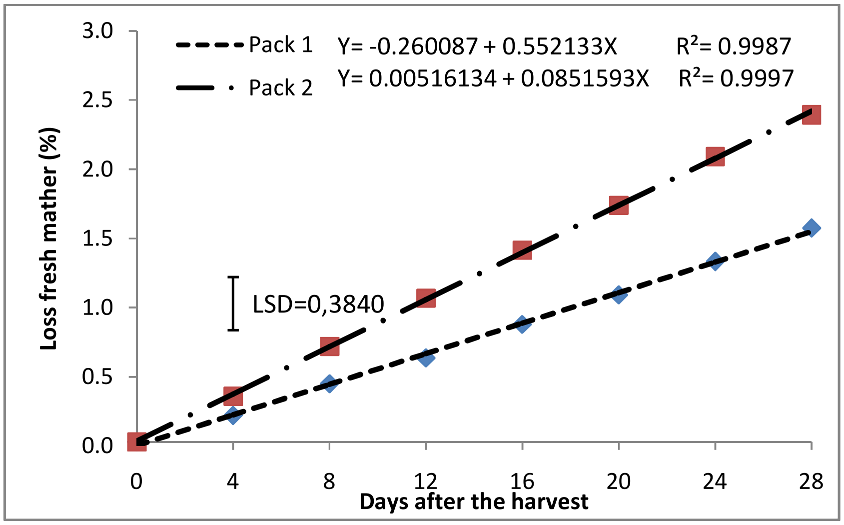

Fig. 2. Loss of fresh matter in atemoya fruits stored in PACK1 and PACK2 and maintained at 15± 1°C and 85± 5% RH for 28 days

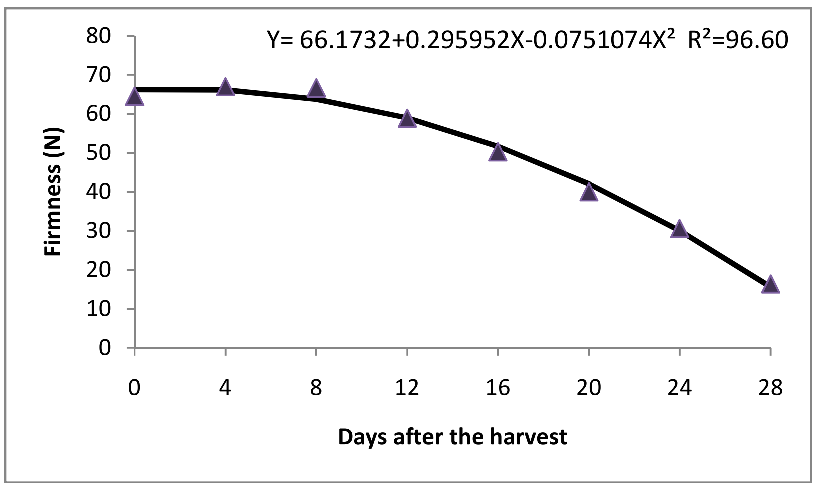

Fig. 3. Firmness in atemoya fruits stored in PACK1 and PACK2 and maintained at 15± 1°C and 85± 5% RH for 28 days

Throughout the evaluation period occurred a decline in pH values for the fruits on both packages. The fruits in PACK1and PACK2 showed average values of 5.63 and 5.54 (Fig. 5), respectively. The LSD of 0.0625 occurred at days 0, 12, 20 and 24 of the storage period. The average initial and final values were, respectively, 5.97 and 5.64 for the fruits in PACK1 and 5.73 to 5.59 for the fruits in PACK2. Researchers already observed in their studies a clear trend between pH reduction and ripening progress in anonaceae [20,27].

Over the trial period there was a progressive, however slight, increase in titratable acidity (TA). There was a significant effect on the interaction packaging * storage period, though no regression model was fitted to the PACK1 data. Fruits stored in PACK1 had initial and final average values of 0.14 g and 0.19 g of citric acid $100L^{-1}$ of juice, respectively, and the ones stored in the PACK2 showed increased mean value, from 0.13 g to 0.20 g of citric acid $100L^{-1}$ of juice (Fig. 6). In studies on refrigerated storage of atemoyas cv. PR3 [6], cv. African Pride [22] and cv. Gefner [20], increased acidity over time was identified, being this a peculiar characteristic of the species.

For peel color, it was observed a slight decrease in the values of the three variables at the end of storage. There was a significant effect on the interaction packaging * storage period for L* and C* variables. For L*, no regression model was fitted to the PACK1 data (Fig. 7). The fruits showed fluctuations in the values of L*,with average initial and final values, respectively, of 58.83° to 55.11°, in the PACK1, and 57.82° to 57.06° in the PACK2.

There was a slight decrease in intensity, and the values of C* increased from 39.15 to 20.34° and from 38.92 to 19.64° from the first to the 28th days, for fruits in PACK1 and PACK2, respectively (Fig. 8). The C* expresses color intensity, the saturation in terms of pigments. In this study, the results of the slight reduction demonstrate that fruits showed color intensity at the end of 28 days.

The h° values of the fruits stored in PACK1 decreased from 99.94 to 95.70° and in the PACK2 from 100.96 to 97.63° (Fig. 9). The h° is the value, in degrees, which corresponds to the tridimensional color diagram 0° (red), 90° (yellow), 180° (green) and 270° (blue). The results of this study show that there was a reduction of green color intensity in the fruit peel, demonstrating ripening.

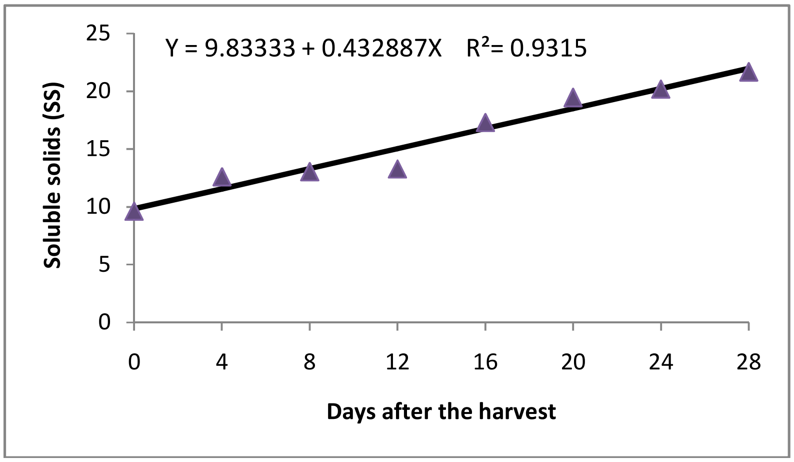

Fig. 4. Soluble solids in atemoya fruits stored in PACK1 and PACK2 and maintained at 15± 1°C and 85± 5% RH for 28 days

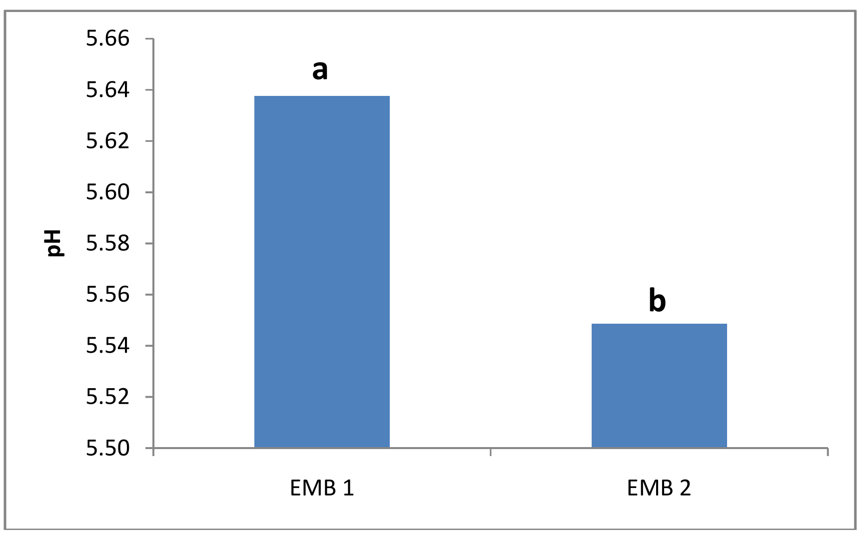

Fig. 5. Mean pH values of atemoya fruits stored in PACK1 and PACK2 and maintained at 15 ± 1°C and 85 ± 5% RH for 28 days. Means followed by different lowercase letters differ statistically by the Tukey test at 5% significance

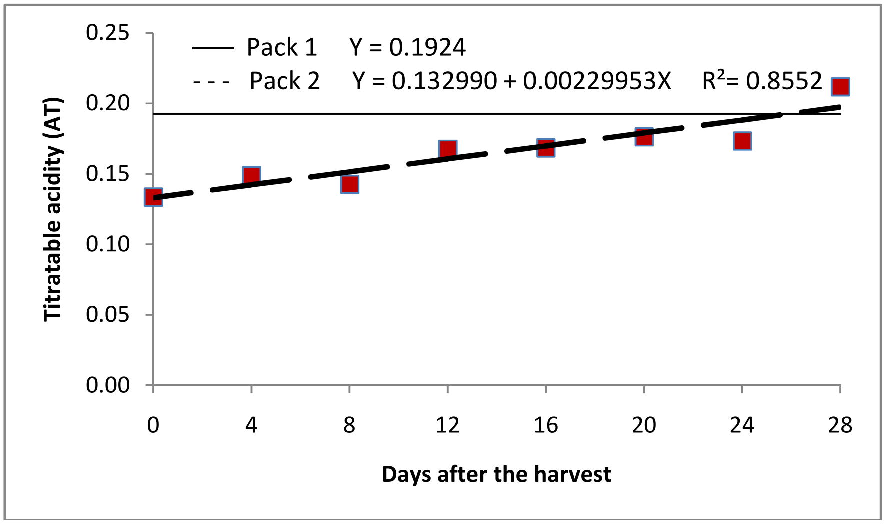

Fig. 6. Titratable acidity in atemoya fruits stored in PACK1 and PACK2 and maintained at 15± 1°C and 85± 5% RH for 28 days

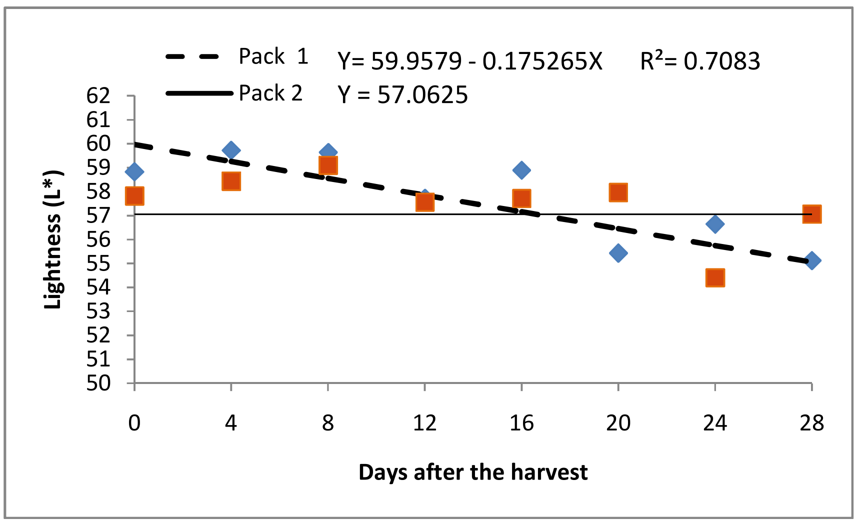

Fig. 7. Lightness in atemoya fruits stored in PACK1 and PACK2 and maintained at 15± 1°C and 85± 5% RH for 28 days

The fast peel darkening in anonaceae is reported in experiments with no packages. Fir instance, atemoyas cv. African Pride, unpackaged, at 17 days at 14.5°C, showed senescence stains on the peel [22], and also unpackaged atemoya fruits, stored at 12 and 25°C, respectively, remained for 12 and six days with light green color [28]. The fruit appearance is hindered by darkening. The appearance of the fruit is impaired by darkening, and it is a key quality requirement at the time of purchase by the consumer [29]. So, preservation of the natural appearance of the fruits is of fundamental importance [30]. The results obtained in this study indicate that the tested packages prevented the occurrence of dark spots on the peel, the "chilling" characteristics and the senescence process, and not only delayed ripening, as it made it possible to occur by the 28th day in both packages.

Progressive degradation in starch contents also occurred. The values of the fruits in PACK1 on days 0, 16 and 28 were 18.15%, 12.57% and 5.02%, respectively, and, in the same dates, the values of the fruits in PACK2 were 22.9%, 9.53% and 4.41%, respectively (Fig. 10).

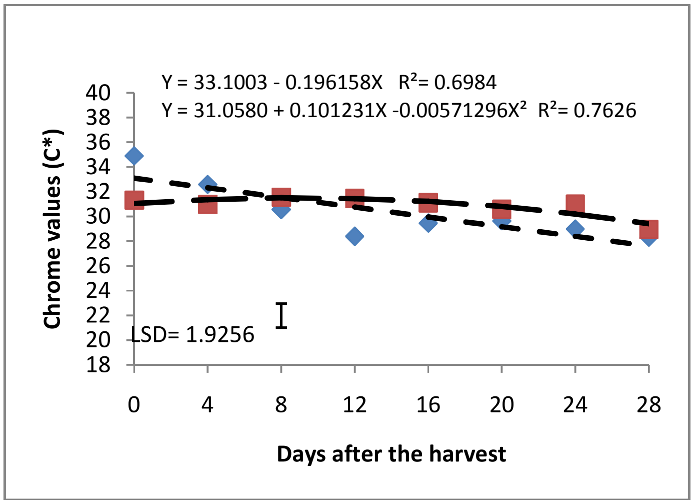

Fig. 8. Chrome values in atemoya fruits stored in PACK1 and PACK2 and maintained at 15± 1°C and 85± 5% RH for 28 days

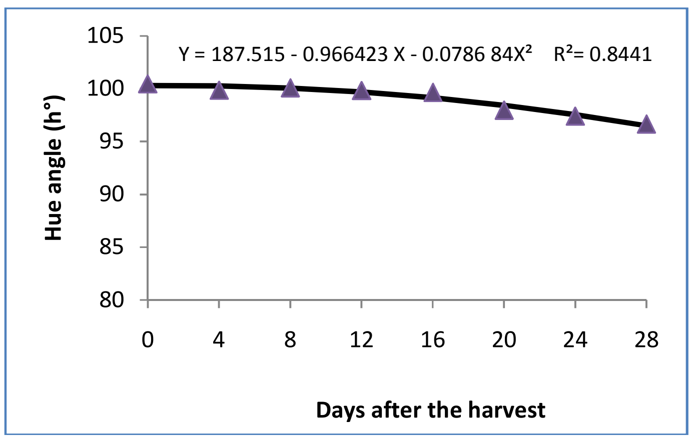

Fig. 9. Hue angle in atemoya fruits stored in PACK1 and PACK2 and maintained at 15± 1°C and 85± 5% RH for 28 days

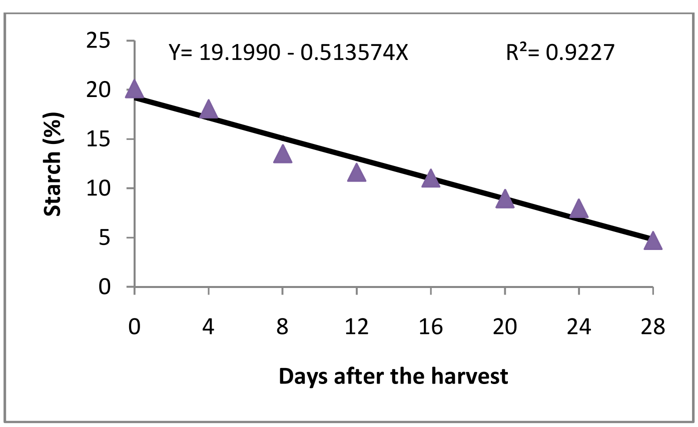

Fig. 10. Starch contents in atemoya fruits stored in PACK1 and PACK2 and maintained at 15± 1°C and 85± 5% RH for 28 days

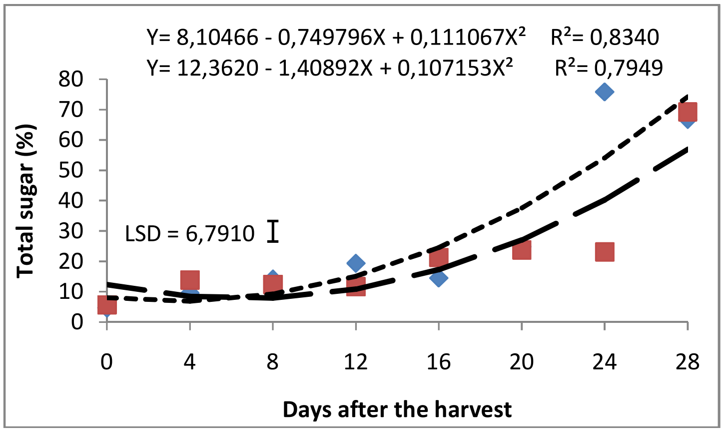

Fig. 11. Total sugar in atemoya fruits stored in PACK1 and PACK2 and maintained at 15± 1°C and 85± 5% RH for 28 days

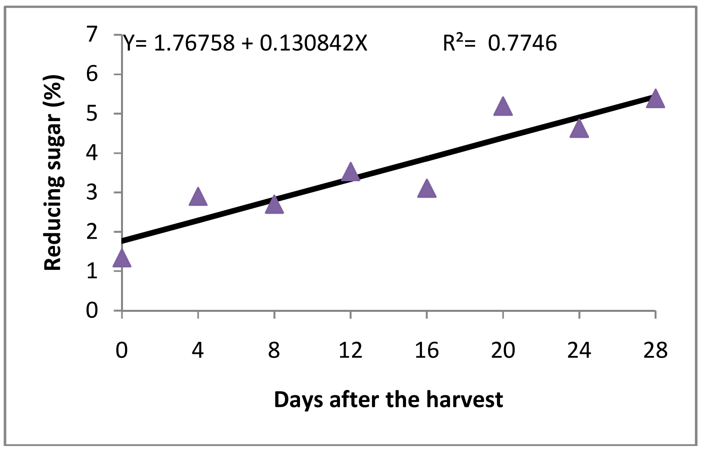

Fig. 12. Reducing sugars in atemoya fruits stored in PACK1 and PACK2 and maintained at 15± 1°C and 85± 5% RH for 28 days

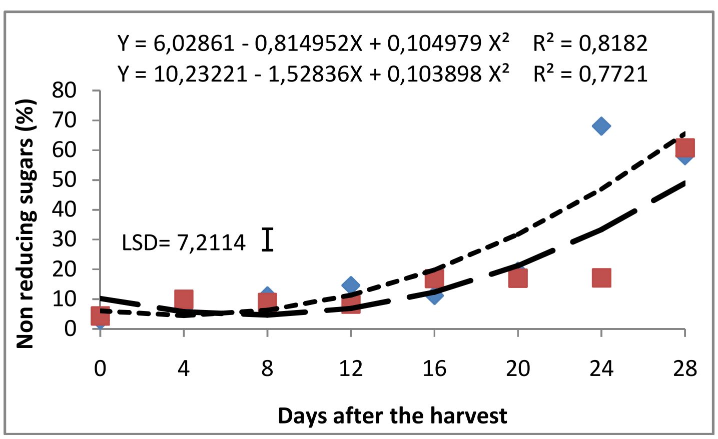

Fig. 13. Non reducing sugars in atemoya fruits stored in PACK1 and PACK2 and maintained at 15± 1°C and 85± 5% RH for 28 days

Simultaneously, there was an increase in the levels of total sugars with LSD between the values of the packages occurred on the 12th day (Fig. 11), and the fruits in PACK1 showed greater solubilization of total sugars. The increase in total sugar contents was parallel to the increase in soluble solids and titratable acidity, with pH and starch decrease, which show fruit ripening. According to Awad [31], from the metabolic process of ripening results the characteristic flavor of the fruit, resulting from the transformation of starch into soluble sugars, the acidity decrease and the astringency disappearance.

Atemoya fruits packed with polyvinyl chloride, stored at 12°C for 18 days, had increased soluble sugars contents in response to slow starch degradation, over time, reaching minimum values at 18° [28].

Synthesis of the reducing sugars (fructose and glucose) occurred gradually. In fruits inside PACK1, the mean values on days 0 and 28 were respectively 1.56% and 5.52%, and the respective values in the PACK2 were 1.12 in 2% and 5.24% (Fig. 12).

The increase in the non-reducing sugars contents (sucrose) occurred markedly from the 16th day and showed LSD from the 24th day (Fig. 13). The high proportion of fructose, which in atemoyas overcomes sucrose, contributes to the extremely sweet taste of this fruit, as the sweetening power of fructose is 1.7 times higher than that of sucrose [32].

4. CONCLUSION

The result of experiment 1 justifies the need of the modified atmosphere to store atemoyas under 15°C for 28 days.

The atemoyas storage for 28 days at 15°C provided ripening, as evidenced by changes in the physical and chemical characteristics in both packages. However, from the 24th storage day, reduction of fruit firmness can be an obstacle by reducing the transport resistance.

The lower density package, PACK1, reduced fresh weight loss, allowed greater solubilization of total sugars and non-reducing sugars compared to PACK2.

The PACK1 is the most suited for the atemoya fruits produced in northern Minas Gerais for providing better fruit quality during the 28 days period.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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