QUALITY OF FRESH-CUT AVOCADO (*Persea americana* Mill.) STORED UNDER DIFFERENT TEMPERATURES

Qualidade de abacates (*Persea americana* Mill.) minimally processados armazenados sob diferentes temperaturas

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ABSTRACT

The goal of this work was to evaluate the effect of different storage temperatures on the quality maintenance of fresh-cut 'Fortuna' avocado (*Persea americana* Mill.). The fruit was selected, washed and sanitized with sodium hypochlorite solution (190 ppm total residual chlorinee) for 15 minutes. After that, the tip was cut and the fruit was also cut in halves, peeled and the pit removed, manually. Then the halves were immersed in 0.5% calcium chlorite + 0.5% cysteine solution for 2 minutes, to avoid darkening and packed in rigid plastic covered with 20 micrometer thick plastic wrap (PVC film) with a permeability to O_2, CO_2 and water vapor of 15,000, 80,000 and 390 cm^3/m^2/day, respectively. The product was stored under 3 different temperatures 0, 5, 10°C and evaluated at 5 different storege periods of 0, 2, 3, 5 and 6 days, in a randomized design in a 3x5 factorial. The storage of fresh-cut avocado at 5°C is the best alternative because it determines better maintenance of quality of the avocado. These presented lower darkening of pulp, better scores for appearance and acceptability, lower softening and polyphenoloxidase activity, in comparison to those stored at 0 and 10°C. The fresh-cut avocados stored at 5ºC presented a shelf life of 5 days, based, mainly on, appearance, score 7.3, sited between the concepts "like moderately" and "like very much" on a hedonic scale of 9 points and 86% of acceptability, at the end of 5 days of storage.

Index terms: Appearance, acceptability, enzymes, firmness, avocado, *Persea Americana.*

RESUMO

Objetivou-se avaliar o efeito de diferentes temperaturas de armazenamento na manutenção da qualidade de abacates 'Fortuna' (*Persea americana* Mill.) minimally processados. Os frutos foram lavados e sanificados em solução de hipoclorito de sódio (190 ppm de cloro residual total) por 15 minutos. Posteriormente, efetuou-se a retirada da extremidade onde se insere o pedúnculo, o corte em metades, retirada do caroço e casca, manualmente. Em seguida, as metades foram imersas em solução com cloreto de cálcio 0,5% + cisteína 0,5% durante 2 minutos, para prevenção do escurecimento, e então acondicionadas em embalagens plásticas (PET) rígidas envoltas com filme (PVC) 20 micrometros de espessura e permeabilidade a O_2, CO_2 e vapor d'água de 15.000, 80.000 e 390 cm^3/m^2/ dia respectivamente. Em seguida, foram armazenadas em 3 diferentes temperaturas, 0, 5, 10ºC, as quais foram avaliadas em 5 diferentes tempos de armazenamento (0, 2, 3, 5 e 6 dias), seguindo um delineamento inteiramente casualizado fatorial 3 X 5. O armazenamento a 5ºC de abacates minimamente processados apresenta-se como a melhor alternativa, pois determinou melhor manutenção da qualidade dos abacates. Estes apresentaram, conjuntamente, menor escurecimento da polpa, melhores notas para aparência e aceitabilidade, menor perda da firmeza e atividade da polyphenol oxidase , diferindo-se dos armazenados a 0 e 10ºC. Os abacates minimally processados armazenados a 5ºC apresentaram vida útil de 5 dias baseando-se, principalmente, na aparência nota 7,3, valor este situado entre os conceitos gostei moderadamente e gostei muito na escala hedônica de 9 pontos e 86% de aceitabilidade, ao final dos 5 dias de armazenamento.

Termos para indexação: Aparência, aceitabilidade, enzimas, firmeza, abacate, *Persea americana.*

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INTRODUCTION

The avocado (*Persea americana* Mill.) is a nutritious fruit, rich in unsaturated fatty acids and hydrosoluable vitamins, especially A and C, but its sugar content is low. The fruit could be recommended, as an energy food, for diabetic people (Swisher, 1988). It can be consumed in salads and/or as dessert, being served with sugar or even homogenized with milk. The largest world producer is Mexico, Brazil being in fourth place in the

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ranking, with a production, in 2005, of 173 thousand tons in an area of 12 thousand hectares. The world production is, approximately, 3.2 million tons and an area of 416 thousand hectares (FAO, 2005).

Minimally processed fruits ("fresh-cut") are defined as those that maintain their fresh state, in spite of having suffered physical alterations. They go through a selection process, washing, peeling and cutting until they approach a 100% usable product that is packaged in order to offer, to the consumers, freshness, convenience and nutritional quality (IFPA, 2007).

The quality of the fresh cut products is related to the maintenance of their sensorial characteristics and control of the contaminating microbiota, with maintenance of the quality of the intact fruit (Vilas Boas and Kader, 2001). That quality can be expressed through the indicators, that include nutritional, microbiological, technological and sensorial properties, such as appearance, aroma, flavor and texture (Martens and Baarseth, 1987).

The darkening and the softening constitute limiting factors to the commercialization of fresh cut fruits and vegetables (Vilas Boas and Kader, 2001). The appearance is the first factor that determines the acceptability or rejection of the foods. Therefore, the maintenance of the original color during the entire processing and storage of the foods is the largest and most difficult objective for the processors (Soliva et al., 2001; Almeida and Nogueira, 1995). The enzymatic darkening, catalized by the polyphenol oxidases (PPO) and peroxidases is one of the main problems in the preservation of the avocado pulp (Dorantes et al., 1998). PPO is an enzyme that, in the presence of oxygen, catalyzes the oxidation of phenolic substrates in quinones, these, later, are polimerized, forming brown, red or black pigments (Soliva et al., 2001). In the same way, the peroxidases present typical activity in the phenolic oxidation, using, however, hydrogen peroxide (H_2O_2) as electron donor, also giving origin to the quinones, which once polimerized, give origin the compounds with dark coloration (Chitarra, 2000). Several methods have been used to inhibit the PPO activity in fruits and vegetables: chemical additives (Melo, Vilas Boas and Justo, 2009; Vilas Boas, Reis and Melo, 2009; Melo and Vilas Boas, 2006; Soliva et al., 2002; Soliva et al., 2001; Fujita et al., 1995), exclusion of O_2 (Soliva et al., 2002; Siddiq et al., 1992), pH adjustment (Soliva et al., 2001; Soliva et al., 2002), cooling (Lozano et al., 1994) and thermal treatment. The cooling is the most economical method for the prolonged storage of fresh fruits and vegetables. The other methods for control of darkening are used as a complement to the lowering of the temperature. These methods, such as environmental control or modification, the use of wax on the surface of the products, chemical additives, among others, does not produce good results if they are not associated to the use of low temperatures (Chitarra and Chitarra, 2005). Flitsanov et al. (2000), working with storage of intact avocados under different temperatures observed that avocados stored at 6 and 8ºC softened more quickly than those stored at 2 and 4ºC.

In function of the growth potential of the fresh cut fruit sector in Brazil, as well as the lack of studies, specifically on fresh cut avocado, in this work, the objective was to verify the effect of the use of different storage temperatures on the maintenance of quality of fresh cut avocados.

MATERIAL AND METHODS

The fruits utilized were 'Fortune ' avacados with average diameter, weight, firmness and dry matter values of 9.17 ± 0.7cm, 611.78 ± 66g, 2.9 ± 0.9N and 19 ± 2%, respectively. The fruits were washed with detergent and soon afterwards stored for 12 hours at 10ºC before the processing. Later, they were immersed, for 15 minutes, in hypochlorite solution with 190 ppm of total residual chlorine, soon afterwards, the stalk insertion extremity was removed, the fruits halved longitudinally and the pit and peel manually removed. The halves (average weight and firmness values of 232.0g and 3.4N respectively) were immersed in solution of 0.5% calcium chlorite + 0.5% cysteine chlorhydrate for 2 minutes, according to Melo and Vilas Boas (2006), for prevention of the darkening and, later, were conditioned in rigid plastic (PET) containers, Galvanotek brand,(15, 12 and 5,5 cm of length, width and height respectively) wrapped with a 20 micron thick film (PVC) with an O_2, CO_2 and water vapor permeability of 15,000, 80,000 and 390 cm^3/m^2/day respectively. The experiment was carried out in the Fruit and Vegetable Post Harvest Laboratory of the Food Science Department of the Federal University of Lavras/MG, following an entirely casualized layout, in 3X5 factorial corresponding to 3 storage temperatures (0, 5 and 10ºC) and five analysis periods (0, 2, 3, 5 and 6 days of storage), with three repetitions, the experimental portion being made up of two halves. The sensorial evaluation was done, following a block layout, made up of 50 blocks (50 testers). The sensorial acceptability of the appearance was evaluated until the sixth day of storage (0, 2, 3, 5 and 6 days) and that of flavor, was evaluated until the third day (0, 2 and 3 days), following which, there was no response aboutthe microbiological quality of the product. The following analyses in the evaluation periods took place: **pulp color**

(value L *): determined, in four distinct regions in a same half, using a Minolta, model CR 400 Chroma Meter-colorimeter, measuring the L *value that varies from white (value =100) to black (value = 0); **sensorial analysis of appearance acceptance, flavor and even purchase intention**: accomplished through the Consumers Test (Meilgaard et al., 1999) in a supermarket of the municipal district of Lavras-MG, using 50 testers, in other words, potential consumers. The appearance and flavor of the product was evaluated, using a mixed nine point structured hedonic scale (9- extremly liked; 1- extremly disliked) and the purchase intention in which the testers responded on the evaluation chart if they would or would not buy the product; **polyphenol oxidase (PPO) and peroxidase (PER) enzyme activity:** the extraction of PPO and PER was carried out according to the method described by Matsumo and Uritami (1972). The frozen tissue was homogenized in a polytron, with 0.05 M, pH 7.0 phosphate buffer and immediately filtered in organza. The obtained homogenate was centrifuged for 10 min at 5,000 rpm at 0ºC temperature. The resulting supernatant was used for the enzymatic activity determination. The determination of PPO was done according to the method described by Teisson (1979). An 1mL aliquot of enzymatic extract was combined with 3.6 mL of 0.1 M, pH 7 phosphate buffer and 0.1 mL of catechol 10 mm. The obtained solution was incubated during 30 min at 30ºC, and the reaction was interrupted by the addition of 0.1 mL of 2 N perchloric acid. The enzymatic activity was expressed as a unit (enzymatic activity capable to alter 0.0001 of absorbance at 395 nm) of gram of fresh pulp per minute ($UAE.g^{-1}.min^{-1}$). The determination of the PER activity was carried out according to the method described by Matsumo and Uritani (1972). A 3mL aliquot of enzymatic extract was pipeted over a solution containing 5mL of citrate phosphate buffer 0.02 M, pH 5, 0.5 mL of hydrogen peroxide and 0.5 mL of guaiacol. The solution was incubated at 30ºC for 5 min, and the reaction interrupted by the addition of 1 mL of 30% sodium bisulfite. The activity of the PER enzyme was expressed as a unit (activity capable to alter 0.001 of absorbance at 470 nm) per gram of fresh pulp per minute ($UAE.g^{-1}.min^{-1}$).

Firmness: determined with the aid of a texture analyzer model TA.X2i, using an 8 mm diameter (P/6N) stainless steel probe, that measured the penetration force in the fruit pulp, in four places in a same avocado half, at a speed of 10 mm/s and at a maximum of penetration distance of 10 mm, these values being previously fixed. The firmness of the fruits was expressed in Newtons (N);

The data was first analyzed through variance analysis (ANOVA) and, later regression and/or Tukey test, using the statistical program SISVAR version 4.0 (Ferreira, 2000).

RESULTS AND DISCUSSION

There was an interactive effect between the temperature and storage time factors on the L * value (color of the pulp), appearance and acceptability of the avocado halves (Illustrations 1, 2 and 3). In Figure1, a decrease is observed in the L *value, indicating that there was surface darkening of the fruit pulp, in spite of the temperatures used during storage. The fruits stored at 10°C presented, on average, lower L * values that the others, in other words, higher pulp darkening, after the 3rd day of storage.

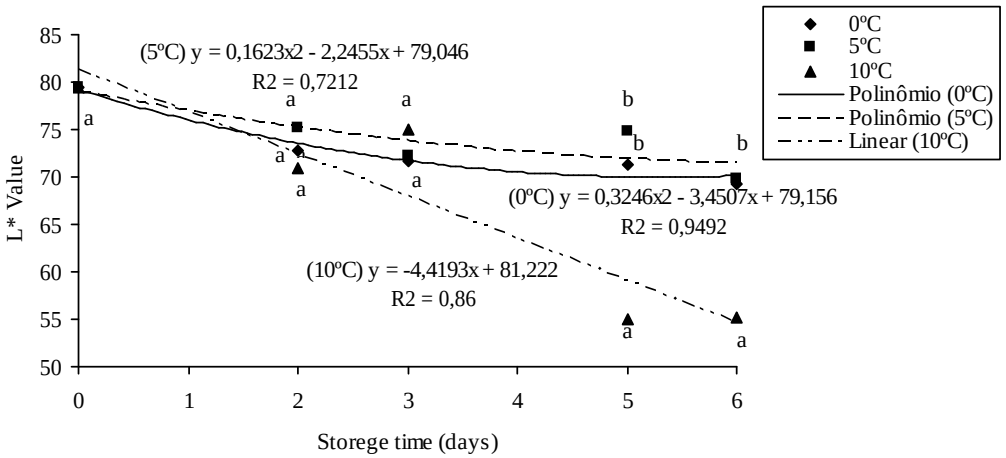

Figure 1 – Color of pulp surface (L*value) of fresh cut avocados during storage, under different temperatures. Points on the vertical followed by the same letter are equal among themselves by the Tukey Test ($p<0,05$).

On analysis of Figures 2 and 3 it can be noticed that after only the 2nd day of storage, there is an effect of the temperatures on the appearance and purchase intention (PI) of the product. The fruits stored at 5ºC presented, on average, better appearance and PI, followed by those stored at 0ºC and 10ºC, on the 2nd, 3rd and 5th days. On the 6th day, the fruits under 0ºC presented, on average, better appearance and PI, followed by the fruits stored at 5ºC and 10ºC, respectively. The fruits under 5ºC presented, on average, from 0 to the 5th day of storage, scores between 8.53 and 7.53, located between the concepts "I liked very much" and "I moderately liked", and PI from 92% to 86%, showing 5ºC to be the best temperature for the storage of this product. Such results are agree with those of pulp color, which show that the fruits stored at 5ºC and 0ºC present better coloration (higher L *value).

Freire et al. (2002), working with fresh cut hydroponic lettuce cv. Regina observed that the product stored at 2ºC presented better sensorial quality than that at 10ºC, this quality measured through the color, intensity of central rib and border darkening, global impression, among others. These results agree with those presented in the present work, which verified the best sensorial quality, appraised through the acceptance test, of the avocados stored at 5ºC followed by those at 0ºC. The

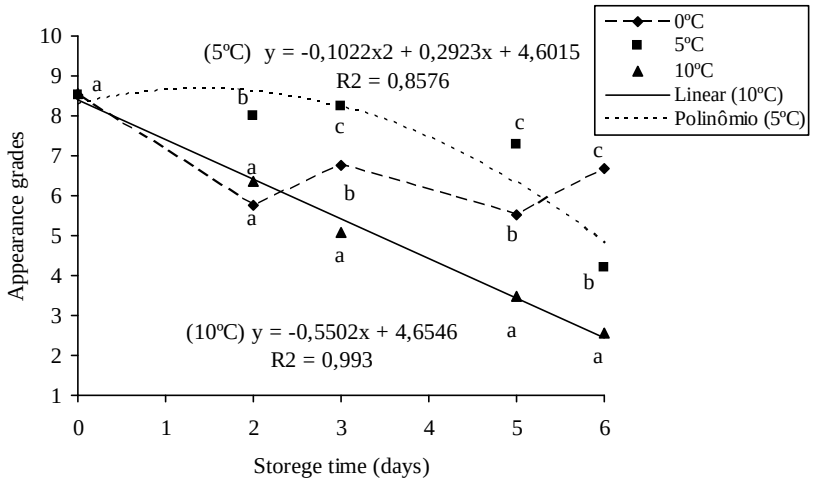

Figure 2 – Appearance of fresh cut avocados during storage under different temperatures. Points on the vertical followed by the same letter are the same among themselves by the Tukey Test (p<0,05).

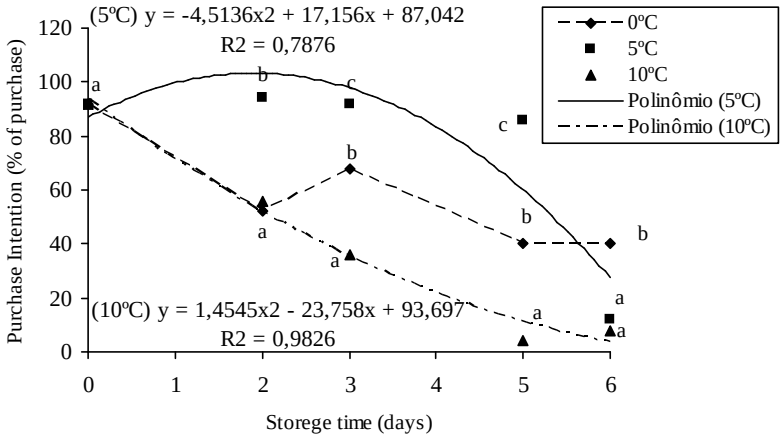

Figure 3 – Purchase intention of fresh cut avocados during storage under different temperatures. Points on the vertical followed by the same letter are the same among themselves by the Tukey Test (p<0,05).

appropriate use of low temperatures in the storage of vegetables leads to a reduction in the activity of several enzymes responsible for the deterioration of the product, being effective in the shelf life extension and quality maintenance of vegetables, be them *in natura* or minimally processed.

The flavor was evaluated until the third day of storage, having only been influenced by the storage time factor (Illustration 4). A decrease was noticed in the flavor scores until the 3rd day, although the fruits on the third day still presented, on average, score 6.2, located between the concepts "I moderately liked" and "I slightly liked". There was no significant effect of the storage temperatures on the flavor.

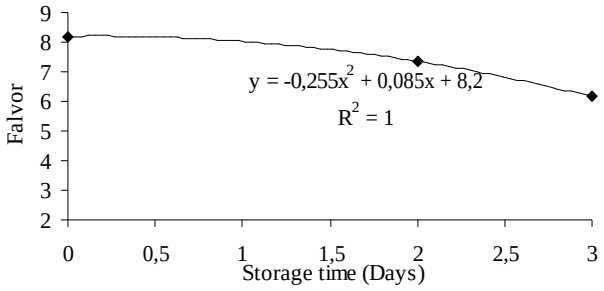

Figure 4 – Average flavor values during storage of fresh cut avocados stored under different temperatures.

The PPO activity was influenced by the time and storage temperature factors, separately, while the PER activity, only by the storage time(Table 1 and Figures 5 and 6).

Table 1 – Average values of polyphenol oxidase (PPO) activity of avocados, fresh cut and stored under different temperatures, followed by the Tukey Test ($p<0,05$).

Storage Temperature	PPO Activity ($UAE.g^{-1}.min^{-1}$)
0ºC	328.37ab
5ºC	308.11[a]
10ºC	369.54b

Averages followed by the same letter, in the columns, are equal among themselves by the Tukey Test ($p<0.05$)

It is observed in Table 1, that there is a higher PPO activity in the fruits stored at 10ºC, differing statistically ($p < 0.05$) from those under 5ºC (lower activity). The avocado halves stored at 0ºC presented PPO activity statistically the same to those under 5 and 10ºC. Those results agree

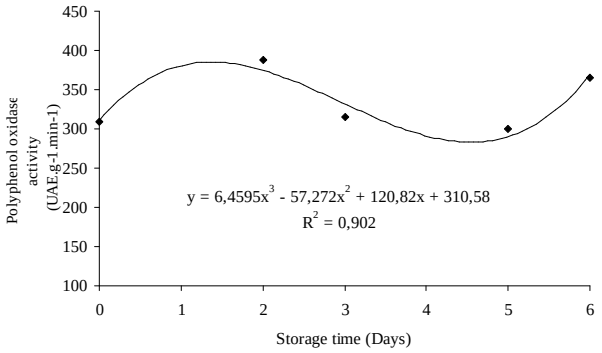

Figure 5 – Activity of polyphenol oxidase ($UAE.g^{-1}.min^{-1}$) of fresh cut avocados during storage, under different temperatures.

with the results of the L * value (pulp color). Soliva et al. (2001), evaluating the effect of different chemicals and environments on the prevention of darkening of avocado purée stored under refrigeration (4ºC), observed that purées, without any chemical treatment and stored under a normal environment presented higher pulp darkening and higher PPO activity, behavior similar to that verified in the present work.

The PPO activity presented, on average, an increase until the 2nd day of storage with a subsequent decline to the 5th day and quick ascension to the 6th day. These results agree with that of the L *value (pulp surface color) which points to an increase in the darkening of the pulp during storage (Illustration 1).

The oxidation of phenolic compounds can also result from the peroxidase (PER) activity, that is related, for instance, to alterations in the color and to the development of strange aromas during storage. Thus, a high rate of enzymatic activity implies a high deterioration potential of the sensorial characteristics of the fruit, reducing their shelf life (Lima et al., 2002). According to Vilas Boas et al. (2007) the peroxidase also contributes, in an indirect way, to the darkening of fresh cut products, destruturing the cellular membranes, reducing their selective permeability; even promoting chain reactions that lead to free radical formation that can cause damage to the organelles and membranes, able to alter the sensorial characteristics of the product. Therefore, a high rate of enzymatic activity implies a high deterioration potential of the sensorial characteristics of the fruit, reducing their shelf life (Lima et al., 2002). The peroxidase activity increased with the storage of the avocados fresh cut (Illustration 6). That increase might have contributed to

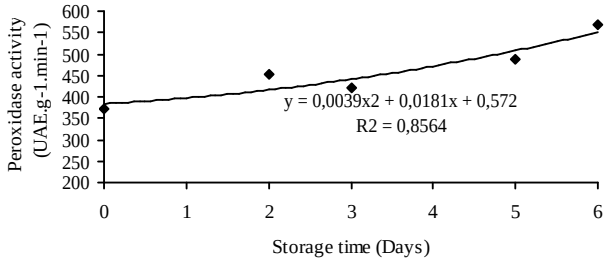

Figure 6 – Peroxidase activity (UAE.g^{-1}.min^{-1}) of fresh cut avacados during storage, under different temperatures.

the modification of the flavor and to the darkening occurrence in the fruit pulp during the storage, mainly in those stored under 10ºC.

Melo and Vilas Boas (2006), working with the application of different chemical for the prevention of the darkening of fresh cut 'Apple ' bananas also observed an increase of the PER activity during storage, in spite of the chemical treatments.

There was a significant effect of the interaction between the temperature and storage time factors on fruit firmness (Illustration 7). An accentuated firmness decrease was observed in the avocado halves under 0ºC followed by those at 10ºC. The halves stored at 5ºC presented higher pulp firmness stability the during storage. The products submitted to 10ºC presented higher loss of firmness probably due to their presenting more intense metabolic activity than those at 5ºC. Those stored at 0ºC, although having a less intense metabolism, might have suffered some damage process in the cellular membranes, such as change of state of the their lipids caused by the low temperature, affecting the cellular integrity and, consequently, the firmness. It can also be observed, in Figure 7, that on the 3rd day of storage the product stored the 0ºC presented lower firmness than the fruits under 10ºC however, these presented a firmness statistically equal to the product at 5ºC. Starting from the 3rd day of storage the halves stored at 5ºC presented, on average, higher firmness than the others (0 and 10ºC), which presented statistically equal firmness until the end of the storage.

Flitsanov et al., (2000), working with storage of intact avocados under different temperatures, observed that during four weeks of storage under low temperatures (2 and 4ºC) there was an insignificant decrease in the firmness of the fruits, which presented firmness equal to 89.2 N and 79.2 N, respectively, until the fourth week of storage, while, the fruits under higher storage temperatures (6 and 8ºC) altered their firmness more significantly to 12.5 N and 10.9 N, respectively, at the end of this period. Such results, demonstrate that the lowering of the temperature is efficient in the maintenance of the firmness and, consequently, in the increase of the postharvest life of vegetables *in natura*, as long as the low temperature tolerance limits for each species and/or cultivar are respected, avoiding the damage caused by the cold.

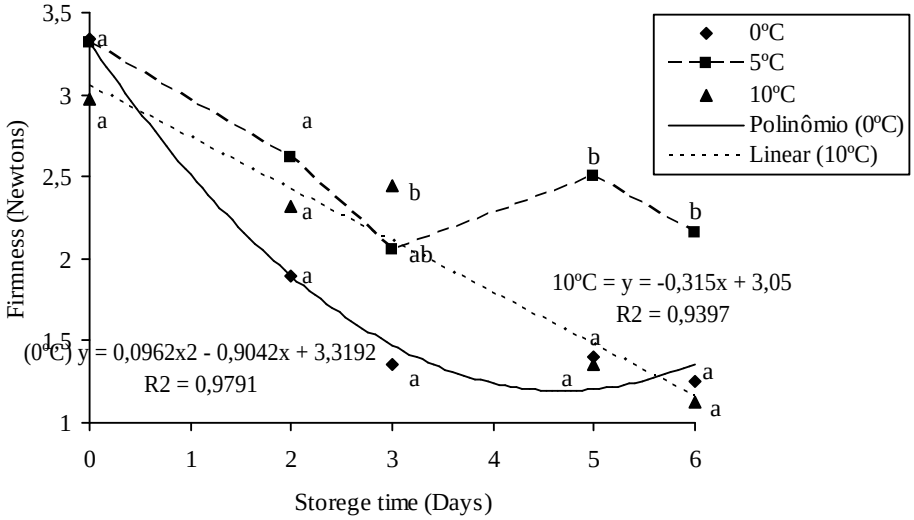

Figure 7 – Firmness (N) of fresh cut avocados during storage, under different temperatures. Points on the vertical followed by the same letter are the same among themselves by the Tukey Test ($p<0,05$).

CONCLUSIONS

The storage of fresh cut 'Fortuna ' avocados, submitted to the application of 0.5% cysteine chlorhydrate + 0.5% calcium chlorite, at 5ºC is the most appropriate for determining better appearance and purchase intention, higher firmness maintenance and lower polyphenol oxidase activity, while storage at 10ºC is not recommended due to causing changes in the pulp surface color, bad appearance and low purchase intention.

'Fortuna ' avocados, frech cut, submitted to the application of 0.5% cysteine chlorhydrate + 0.5% calcium chlorite and stored at 5ºC possess a shelf life of 5 days based on the scores above 7.0 for appearance and purchase intention above 86% at the end of this period.

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