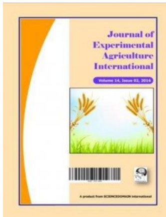

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Effect of Cassava Starch Coating on the Quality and Shelf Life of Prickly Pear in Refrigerated Storage

Valtânia Xavier Nunes[1*], Núbia Xavier Nunes[1], Juceliandy Mendes da Silva[1], Sarah Nadja Araújo Fonsesa[1], Mariana Oliveira de Jesus[1], Eliene Almeida Paraizo[1], Gisele Polete Mizobutsi[1] and Carlos Eduardo Magalhães dos Santos[1]

[1]Department of Plant Science, Universidade Federal de Viçosa, Viçosa-MG, Brazil.

Authors' contributions

This work was carried out in collaboration among all authors. Author VXN designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors NXN, JMS, SNAF, MOJ and EAP managed the analyses of the study. Authors GPM and CEMS managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

In Brazil, the prickly pear has been gaining more and more attention, mainly due to its nutritional health promotion benefits. However, its postharvest conservation is still incipient The aim of this study was to evaluate the use of cassava starch in different concentrations in relation to quality preservation and postharvest shelf life prolongation of prickly pear stored at 10 °C and relative humidity of 95%. Fruit were harvested at maturation stage III, in plants with 8 years of age, in the municipality of Janaúba - MG. Then they were selected, sanitized and immersed in sulutions of cassava starch at 0; 1; 2 and 3% for 1 minute and stored at 10 ± 1 ◦C and relative humidity of 95 ± 5%, for 25 days, and evaluated every five days. The designed trial consisted of a completely randomized trial, in a 4x6 factorial scheme: four concentrations of cassava starch and six periods of evaluations (0, 5, 10, 15, 20 and 25 days), with four replications. Fruit were evaluated for physical,

*Corresponding author: E-mail: tania_chavier@yahoo.com.br;

chemical and nutritional characteristics. During storage were observed weight loss, firmness loss, chlorophyll degradation, acidity reduction and ascorbic acid, with increase of soluble solids, total sugars and carotenoids in fruit. The higher the cassava starch concentration, the greater the maintenance of fruit quality. The 3% cassava starch coating was the most efficient at delaying the weight loss, decay, softening and wilting in the fruits, the main characteristics that affect the quality of prickly pear. However, this concentration presented, as an inconvenience, coating peeling at the end of storage.

Keywords: Opuntia ficus-indica; edible coating; storage; conservation.

1. INTRODUCTION

Cactus pear [*Opuntia ficus-indica* (L.) Mill.] is a plant of the cactaceae family, cultivated for fruit production in various places of the world, such as Italy, South Africa, Chile and Israel, highlighting Mexico as the largest producer worldwide. The prickly pear is an oval, sweet and juicy berry that has been arousing interest, more and more, in national and international markets mainly due to the nutritional benefits of health promotion since they contain taurine, proline, phenolic compounds, betalains and vitamins (mainly A and C); Besides the possibility of exploring the medicinal properties, it has been demonstrated that they have several activities, among them: antioxidant, anti-inflammatory, hypoglycemic and anti-diabetic properties [1,2,3,4,5].

In Brazil, the cactus pear is mainly cultivated for animal feeding; presenting extensive cultivated areas, with higher occurrence in the northeastern semiarid [6]. The commercial production of fruits of this species in Brazil is concentrated in the State of São Paulo, highlighting the city of Valinhos as the main producing region [7], presenting excellent acceptance in the foreign market and high price in the domestic market, with good economic returns to producers. In CEASA [8], it was sold at a price of R $ 10.00 to R $ 15.00 per kilo (kg). Based on this, prickly pear stands as one of the resources with the greatest potential to add value and increase the income of the population of the Brazilian semiarid.

However, prickly pear are characterized as highly perishable fruit, mainly due to inadequate harvesting practices, especially when the fruit are twisted by rotation around the cladode, which causes a physical lesion at the base of the fruit, causing acceleration of the microbial growth. For prickly pear the deterioration factors of are pathological infections, peel browning and dehydration. Storage at room temperature favours decay, fruit weight loss, wilting, softening and off-flavor development, while the low temperatures promoted chilling injury [9,10,11]. Thus, it is necessary to seek suitable techniques for keeping quality, packaging and postharvest handling, which allow a better use and marketing of the fruit.

The refrigerated storage is the main way for keeping quality in plant products during postharvest period, being able to be combined with other conservation techniques to potentiate its effects [10]. The association of atmospheric modification with the use of edible coatings is a promising alternative and can be used to inhib moisture loss, oxygen and carbon dioxide, thus improving the intrinsic characteristics and integrity of the fruit and vegetables [12]. Cassava starch is produced in large scale in Brazil and presents good characteristics for the formation of resistant and transparent films, being efficient barrier for water loss, giving good appearance and intense brightness to the fruit. In addition, It is edible and present low price when compared to the other commercial waxes [13,14].

Studies using cooling and modified atmosphere, demonstrate positive results prickly pear, especially for the control of the weight loss and extend of the postharvest life. However, the use of the modified atmosphere, both active and passive, has caused a drastic reduction in the oxygen partial pressure inside the packages due to the increase in the metabolic activity of the fruits when they are stored at higher temperatures, promoting microbial growth, fermentation and rotting of the fruit [15,16,11]. Thus, it is necessary to use edible films associated with low temperature.

Cassava starch coating has been used in some fruit, mexerica-do-rio [17], tangerines ponkan [18] and strawberries [19]. And has been shown to be efficient in extending postharvest shelf life especially when associated with cooling. However, there is no published information on the use of cassava starch in the postharvest conservation of prickly pear produced in the Brazilian semiarid region. Thus, the aim of this study was to evaluate the use of cassava starch in different concentrations in maintaining quality and prolonging the postharvest shelf life of prickly pear stored at 10°C and 95%.

2. MATERIALS AND METHODS

2.1 Prickly Pear

Physiologically mature prickly pear cv. Gigante were obtained corresponding to stage III of maturation (yellow green coloration) according to the classification described by Munsell [20]. Prickly pears free from physical and microbiological deteriorations were selected. Fruit were washed, manually peeled, disinfected in a 2% hypochlorite solution for 15 min and then washed under running water. Excess of water was removed with absorbent paper.

2.2 Cassava Starch Solution

Cassava starch solution was prepared by placing 1 liter of distilled water: starch 1% - 10 g; 2% starch – 20 g; 3% starch - 30 g; (dry material). The solution was poured into a beaker, warmed (70°C), and blended, using a homogenizer. The solution was then allowed to stand at room temperature (25°C).

2.3 Fruit Coating and Storage

Peeled prickly pears were randomly sorted and divided in four batches. Four different treatments were performed: Control (without any treatment) and three concentrations cassava starch (1, 2 and 3%). Prickly pears were immersed once in the cassava starch solution for 1 min. The superficial moisture was removed at 25°C by natural drying. Prickly pears were then placed into plastic boxes and stored at 10 ± 1°C and 95 ± 5% relative humidity conditions. The experiment was conducted in a completely randomized design, in a 4x6 factorial scheme, with 4 treatments and 6 evaluation periods (0, 5, 10, 15, 20 and 25 days). Four replicates per treatment and three fruits per experimental unit were used.

2.4 Analyzes

2.4.1 Physical analysis

Weigth loss - Determined, in grams, with the aid of a semi-analytical balance. The results were expressed as a percentage, considering the difference between the initial weigth and that obtained at each storage time interval (days).

Firmness - A texturometer was used (Brookfield model CT3 10 KG). The firmness was measured in Newton (N), in the middle region of the fruit with bark, being determined with a tip of 2.5 cm in length and 4 mm in diameter by the force of penetration in the fruit pulp

Color- The L (lightness), a* (“green” to “+red”), b* (“blue” to “+yellow”), c* represents the vividness of color (vivid to pale color) and h* (corresponds to the intensity of light or dark color). color parameters were measured in the equatorial zone of unpeeled prickly pears using a colorimetern in the reflectance mode.

2.4.2 Chemical analyzes

Total soluble sugars - Extracted with ethyl alcohol and determined by the method of Antrona. The sample was submitted to the reading in a spectrophotometer at 620nm and the results expressed in percentage [21].

Soluble solids (SSC) - The refractometer was prepared by refractometry using 2 g of crushed fruit pulp and a digital refractometer (Atago, model N-1α) [22].

Relation SSC/TA - Also called ratio or maturation index, where the soluble solids value was divided by that of titratable acidity and the result expressed in pure number with two decimal places.

Titratable acidity - This parameter was determined by titrating 10 g of the pulp and 90 ml of distilled water 0.1 N NaOH solution by adding three drops of 1% phenolphthalein as indicator. According to equation = (100 *(V * N* fc * fa)) P = Result in mg citric acid per $100g^{-1}$ of pulp. V = volume spent / N = NaOH normality / Fc = correction factor of normality / Fa = acid correction factor / P = sample weight [22].

2.4.3 Nutritional analyzes

Ascorbic acid- This parameter was determined by titration with 2,6-dichlorophenolindofenol (DFI) until obtaining a permanent light pink stain, using 2 g of the pulp diluted in 50 mL of 1% oxalic acid. According to equation = 100*Vi*F/Va = Result in mg ascorbic acid per $100g^{-1}$ of pulp. Vi: volume of DCPIP solution spent on sample titration/ Va:

sample volume used in titration/ F: DCPIP factor, in mg ascorbic acid / mL of DCPIP solution [23].

Carotenoids- 2 g of the pulp sample were macerated with a pinch of $CaCO_3$, after maceration it was added 80% acetone and filtered the paper extract. The absorbance was measured in a spectrophotometer at 663 nm, 646 nm and 470 nm, and the carotenoids determined by the chlorophyll difference according to the equations developed by Lichtenthaler [24].

2.5 Statistical Analysis

The data were submitted to analysis of variance and regression using Software SAEG (System of Statistical and Genetic Analysis, v.9.1). The models were chosen based on the significance of the regression coefficient, the coefficient of determination and the potential to explain the biological phenomenon [25].

3. RESULTS

The analysis of variance showed significant interaction (P <0.01) between the tested factors (cassava starch concentrations and storage periods) for the characteristics of weight loss, color (lightness), chroma, angle HUE, firmness, soluble solids content, titratable acidity, SS / AT ratio, ascorbic acid and carotenoids.

3.1 Physical Analysis

There was a significant linear increase in the weight loss of prickly pear during storage. Every 5 days of storage there was an increase of 0.19% of weight loss for all treatments (Fig. 1A). The highest weight losses were observed in uncoated fruit (0% cassava starch, controls). In this treatment, on the 25th day, weight loss was 5.27%.

The prickly pear treated with cassava starch showed the least weight loss. At every 1% increase in cassava starch concentration occurred retention of 0.43% of weight loss, the application of starch to 3% was the most effective at delaying the weight loss of prickly pear.

The prickly pear firmness was adjusted to the linear model, decreasing significantly during storage, every 5 days of storage there was loss 0.70 N in the prickly pear firmness (Fig. 1B). The application of cassava starch coating promoted greater retention of firmness during storage. At every 1% increase in concentration of cassava starch occurred 1.12 N retention in the firmness values. The prickly pears coated with 3% cassava starch and the non coated reached 21.67 and 18.29 N respectively, at the end of the storage period.

In the results obtained for the evaluation of L (lightness) which indicates brightness, this characteristic showed a linear decline along the storage. At each 5 day of storage there was a reduction of 0.17 of the L (lightness) values of the fruit (Fig. 2A). At each 1% of the increase in cassava starch concentration there was an increase of 5.24 in the L (lightness) values.

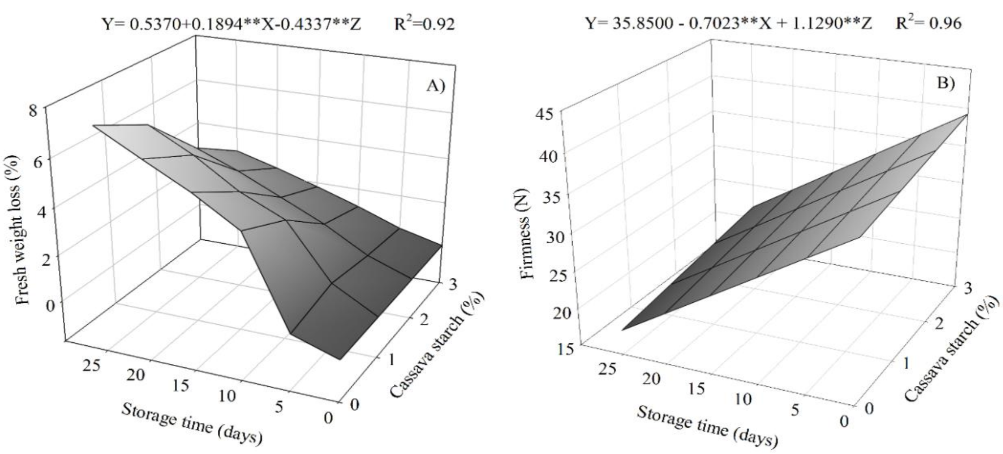

Fig. 1. Fresh weight loss (A), firmness (B) of prickly pears coated with cassava starch and stored at 10°C ± 1°C and 95% ± 5% RH

As for chromaticity, there was a significant linear increase along the storage, with an increase of 0.31 of the chromaticity values every 5 days of storage (Fig. 2B). It was observed values of 43.32; 41.84; 40.36; 38,88 for the treatments 0, 1, 2 and 3% cassava starch at 25 days.

There was a linear reduction of the chromaticity with the increase of cassava starch concentrations, varying of 43.32 in no coated fruits by cassava starch to 38.88 in fruits coated with cassava starch at 3%. Thus, showing effectiveness of the coating in color retention.

The color angle (h°) can vary from 0° to 270°, 0° corresponds to red, 90° corresponds to yellow, 180° to green and 270° to blue.

During storage, the values of the (h°) angle were significantly reduced (Fig. 3), showing a reduction of 0.40 every 5 days of evaluation. The color of the prickly pear was significantly affected by the application of cassava starch, the angle (h °) decreased rapidly in fruits that were not coated with cassava starch, whereas the 3% coating maintained the coloration of the Greener fruits, which resulted in values of this angle being h° = 92.38 for the prickly pear coated to 3% cassava starch and (h°) = 89.46 for the control at 25 days storage.

3.2 Chemical Analysis

The total sugars presented a linear adjustment (Fig. 4A) with a significant increase during the storage, every 5 days of storage there was an increment of 0.19% of sugars. At each 1% increase in cassava starch concentrations there was retention of 0.74% of the total sugars. Therefore, the higher the concentration of cassava starch used in the prickly pear, the smaller was the conversion of starch to total sugars during storage.

Soluble solids increased significantly during storage for all treatments, an increase of 0.19° Brix was observed every 5 days of evaluation (Fig. 4B). It is observed that the higher the concentrations of cassava starch used, the lower were the increments of soluble solids, with retention of 0.34° brix at each 1% increase in the concentration of cassava starch.

The SSC / AT ratio was adjusted to the quadratic model (Fig. 4C) with significant increase during storage. There was an increase of 7.24 every 5 days of evaluation. With a subsequent reduction of 0.13 in the SS / AT ratio at the end of storage. Observing, at 25 days, values of 138.38; 134.20; 130.02; 125.85 respectively, for the treatments 0, 1, 2 and 3% of casava starch. At each 1% increase in cassava starch concentration there was a significant linear retention of 4.17 of the SS / AT ratio.

The titratable acidity in the prickly pear reduced significantly along the storage, adjusting to the quadratic model, while the cassava starch concentration presented linear adjustment (Fig. 4D). As the concentration of cassava starch increased, lower was reduction the acidity of the fruits during storage, reaching values of 0.106; 0.107; 0.109; 0.111 mg/100-1, for the treatments 0, 1, 2 and 3% of cassava starch, respectively, at 25 days.

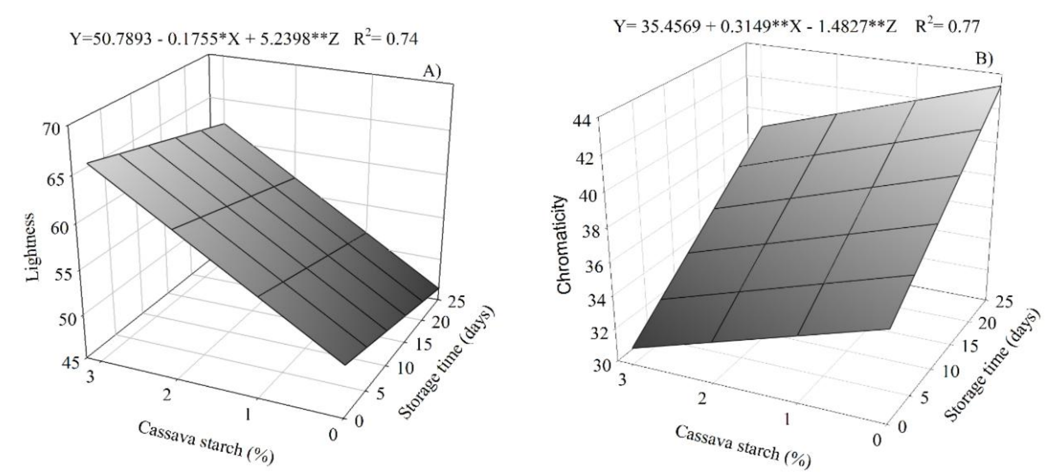

Fig. 2. Lightness (A), chromaticity (B) of prickly pears coated with cassava starch and stored at 10°C ± 1°C and 95% ± 5% RH

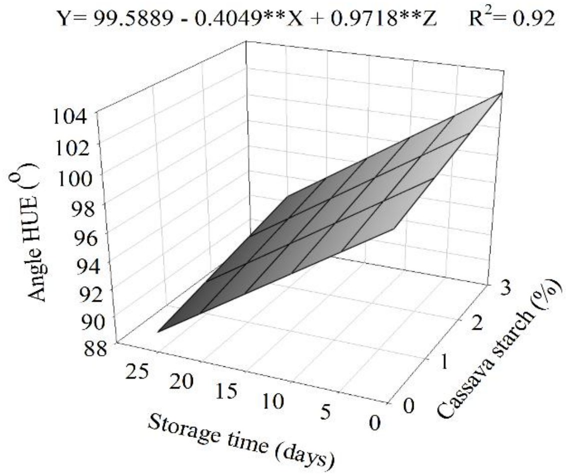

Fig. 3. HUE angle of prickly pears coated with cassava starch and stored at 10°C ± 1°C and 95% ± 5% RH

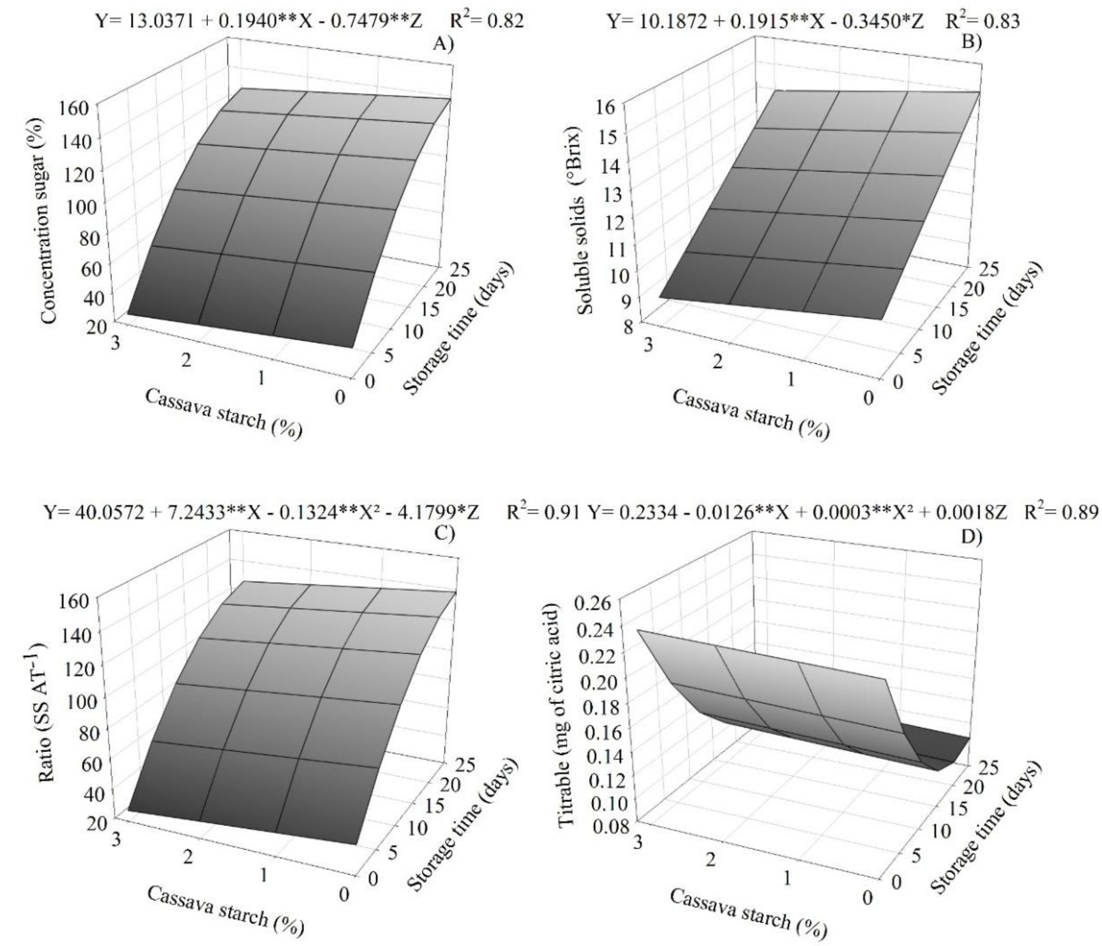

Fig. 4. Total sugar (A), soluble solids content (B), SSC / AT ratio (C), titratable acidity (D) of prickly pears coated with cassava starch and stored at 10°C ± 1°C and 95% ± 5% RH

3.3 Nutritional Analyzes

Ascorbic acid adjusted to the linear model (Fig. 5A) with significant reduction along the storage for all treatments. The cassava starch in the concentrations used in this work were not efficient to maintain the ascorbic acid content in the prickly pear during storage. Ascorbic acid reduced of 29.69; 29,20; 28.70; 28.20 mg / 100-1, for 19.88; 19.39; 18.89; 18.39 mg / 100-1 at 25 days, for 0, 1, 2 and 3% cassava starch coating.

Regarding carotenoids, the results showed linear adjustment (Fig. 5B) with progressive increase during storage for all treatments. For every 5 days of storage there was an increment of 0.09 in the carotenoid contents the prickly pear, showing that with fruit ripening, occurs production or synthesis of carotenoids. It was observed lower carotenoid content with the increase of cassava starch concentrations. Observing at 25 days, values of 5.56; 5.30; 5.04; 4.78 mg 100g-1 respectively, were for treatments 0, 1, 2 and 3% cassava starch coating.

4. DISCUSSION

The weight loss is the main characteristic that affects the quality of prickly pear, It causes wilting, wrinkling of the peel, making it improper for marketing. At the end of storage, it was observed that uncoated fruits presented complete yellowing and dehydrated appearance of the bark, however, their pulp still presented good appearance. The application of cassava starch at 3% was the most effective for delaying fruit weight loss by acting as a physical barrier to the gas exchange and loss of vapor pressure between fruits and the atmosphere. The formation of this physical barrier around fruits reduced the weight loss with greater efficiency because cassava starch is a hydrophilic material with a significant water absorption rate and the effect of reducing water loss is effective for this type of coating.

The cassava starch coating at the highest concentration was the most effective in the prevention of fruit softening, presenting higher resistance along the stored. This demonstrates that the cassava starch is effective at preventing fruit softening caused by loss of turgidity, degradation of the starch, hemicelluloses and pectins found naturally in the cell wall.

Gonzalez et al. [15] point out that the 1mm paraffin wax coating promoted softening due to the high concentration of CO_2 promoted by the high thickness of the coating, which provoked fermentation in the fruits. In this study, the 3% cassava starch coating, despite providing superior efficiency to the other treatments, presented as an inconvenience coating peeling at the end of storage; However, no fruit fermentation was observed. Thus, it is suggested the addition of plasticizing substances such as (glycerin or sorbitol) that avoid the desquamation of the films of cassava starch made in greater concentration.

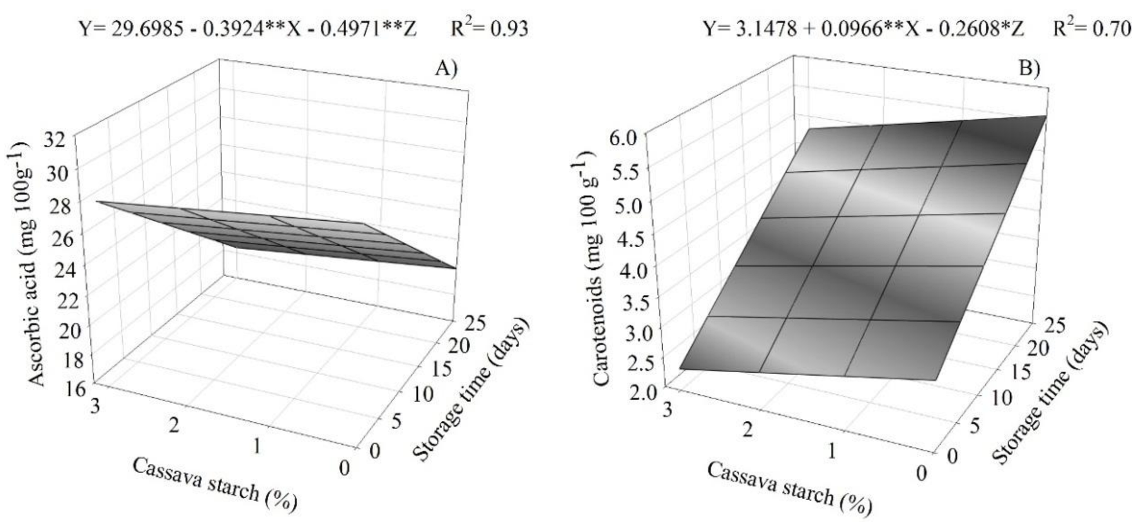

Fig. 5. Ascorbie acid (A), carotenoids (B) of prickly pears coated with cassava starch and stored at 10°C ± 1°C and 95% ± 5% RH

There was a reduction of prickly pear luminosity during the storage. The application of the coatings gave a higher brightness, in prickly pear, proportional to its concentration, resulting in fruits with greater luminosity with the increase of the starch concentration. This characteristic is quite desirable in maintaining the appearance of the fruits, making them more attractive during the commercialization. Similar behavior was verified by Vila et al. [26], who observed intense brightness when treating guavas 'Pedro Sato' with coatings at 2, 3 and 4% cassava starch.

The chromaticity, there was increase along the storage, which indicates the evolution of the color intensity (loss of green color) of the fruit evaluated. Similar results were reported by Ochoa-Velasco and Guerrero-Beltrán [11], they verified color intensity evolution for prickly pear in all storage conditions, and that the major change to the color parameter was in unpackaged prickly pear.

There was a reduction in chromaticity with increasing cassava starch concentrations, showing the effectiveness of the coating in the retention of the green color of the fruit. This behavior is in agreement with Vila et al. [26], who verified green color maintenance in 'Pedro Sato' guavas treated with cassava starch films when compared to the fruits no coating.

The color of the prickly pear peel began with a yellow-green tint on the first day of evaluation, accentuating to a yellow-orange tint along the storage. Being significantly affected by coating application, the hue angle decreased more rapidly in fruit no coating. The coating treatmentes kept the coloration the prickly pear. The higher the concentration of the coating used, the greater the delay in the color change of the epidermis. Thus indicating that the film formed around the fruits possibly reduced its normal respiration, which delayed the degradation of chlorophyll, because the enzymes that cause the degradation of color depend on the concentration of ethylene, which in turn is reduced due to the low oxygen concentration.

The application of the 3% coating provided higher maintenance of the total sugar contents, presenting the lower averages in the pulp of prickly pear during storage, this probably due to the formation of a barrier around the fruit, which reduced with more efficiency the metabolism. Uncoated fruits presented higher total sugar increments. This increase was probably due to the biochemical changes the fruit, such as starch and cell wall degradation. Brito Primo et al. [27], observed an increase in total sugars during storage of prickly pear, whether or not involved in PVC films.

Uncoated fruit presented the greatest increase in soluble solids, demonstrating a high metabolic activity in relation to the prickly pear submitted to the cassava starch coating. Probably, this increase in the soluble solids is due to the concentration of the sugars in function of the loss of water, because prickly pear are characterized as non-climacteric species. Although, according Dimitris et al. [9], there are still contradictions regarding the respiratory pattern of these fruits.

Ochoa-Velasco and Guerrero-Beltrán [28] also observed increments in soluble solids of white prickly pear, Villanueva variety, stored at 9°C. On the other hand, Ochoa-Velasco and Guerrero-Beltrán [11] reported a decrease in soluble solids in white prickly pear (*Opuntia albicarpa*) during 40 days of storage. Already Barrios et al. [29] reported that the Burrona prickly pear variety showed no change during 75 days of storage. Thus, showing variety effect in response to fruit metabolism.

The application of 3% cassava starch conferred a lower SSC / AT ratio during storage, indicating that this concentration was the most efficient in delaying the ripening process and senescence. A similar result was found by Brito Primo et al. [27], when working wifth prickly pear stored under an modified atmosphere by PVC films it was verified an increase at the SSC / AT ratio during refrigerated storage.

The prickly pear treated with cassava starch at 3% concentration showed a lower reduction in titratable acidity during storage. However, in all treatments, an initial acidity decline was observed up to the 20th day of evaluation, with an increment subsequent at the end of storage. However, no anaerobic respiration or fruit fermentation was observed (data not shown). Thus, it is possible to predict that this increase is associated with low respiratory activity at the end of storage, with subsequent senescence that generated an accumulation of acids in the vacuoles, as soluble solids contents increased [30].

It was found degradation of the ascorbic acid content along the storage for all treatments. The use of the cassava starch coating had no positive effect on the maintenance of the ascorbic acid content in this fruit. This fact can be explained due to the rapid degradation of the ascorbic acid content in stored products since it is very unstable and its high degradation is due to the ease of oxidation and enzymatic action of ascorbate oxidase. Some authors also report a reduction in the ascorbic acid content along the storage of fruits [31,17,32].

Prickly pear are rich in carotenoids and these pigments increase with the advancement of maturation. The fruit treated with 3% of cassava starch presented greater control in the production of carotenoids, showing that this concentration was the best to contain the evolution of maturation. In addition, a correlation can be observed between the carotenoids and the increase of the color parameter. This indicates a loss of green color (chlorophyll) with an increase in pigment content in fruit pulp.

5. CONCLUSION

The 3% cassava starch coating is effective in delaying the weight loss, softening and dehydration of prickly pear within 25 days, kept under refrigeration at 10°C.

The concentration of 3% cassava starch, despite providing superior efficiency to the 2% concentration, presented peeling of the coating in the end of storage.

It is suggested addition of plasticizing substances, such as: (glycerin or sorbitol), which avoid the desquamation of cassava starch films made in higher concentration, as in this study with 3% cassava starch, since in this concentration the best results were observed.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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