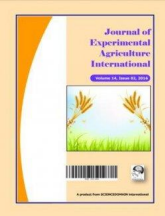

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Physico-chemical Quality Changes of Young Cladodes of "Mexican Elephant Ear" Minimally Processed during Refrigerated Storage

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Authors' contributions

This work was carried out in collaboration between all authors. Author THBG elaborated the study, participated in all the steps of conducting and writing the manuscript. Author FBC consisted of the research supervisor, showed the alternatives of conducting and evaluating the data, assisting in the statistical part of the work. Author AMN decisived in the correction phase, showed alternatives to enrich the information work. Authors YLB and AGFS participated in the process of planning and conducting the experiment in the laboratory. Authors KGS and KPS participated during the physical and chemical evaluations in the laboratory. Author JLS participated during writing assisting to enrich the work. Authors MSS and GNBS participated in the process of planning and conducting the experiment in the field. Author TMG were of paramount importance in the conduction and evaluation of the experiment.

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ABSTRACT

Objective: The study aims to assess the physical-chemical quality of minimally processed young cladodes of the 'Mexican elephant ear' palm over the course of 10 days in storage.
Experimental Design: The experiment was conducted in a completely randomized design, with analyses executed on the 0, 2, 4, 6, 8 and 10 days, with five recurrences utilized.
Place and Duration of the Study: the experiment took place at the Chemistry, Biochemistry and Food Analysis of the Agrifood Science and Technology Center – CCTA of the Federal University of Campina Grande – UFCG, Pombal campus, Paraíba in a period between November 1st and November 11, 2018.
Methodology: A tertiary and quaternary young palm cladodes were harvested at 30 days of age, ranging from 14 to 20cm. The cladodes were taken to the Chemistry Biochemistry and Food Analysis of the Agrifood Science and Technology Center where they were minimally processed and stored in expanded polystyrene trays, wrapped with a layer of PVC film (12µm) at 4±1ºC and 40±5% RH.
Results: During storage, there was a decrease of 10.4% in accumulated fresh mass and an increase of 30% in phenolic compounds in young cladodes of the palm. Probably this result is related to the stress provoked by the minimal processing in which the tissue subject to cutting has physiologically adapted to the healing process.
Conclusion: The increase in the phenolic compounds in young cladodes operates as a protection response strategy to the plant tissue, and do a major role in the functional characteristics when the young cladodes are consumed as a non-conventional edible plant.

Keywords: Non-conventional edible plant; Opuntia tuna; ready for consumption.

1. INTRODUCTION

From Mexican origins, the palm plant of the *Opuntia* genus is utilized in many ways, and in its home country there is a wide range of these plants. It is also found in countries such as Canada, Argentina, Peru, and Brazil, in which its cultivated area is of around 550.000 ha [1].

Brazilian Northeast Region has semiarid climate characteristics, due to the rainfall irregularity for long periods, becoming an ambient where there are difficulties due to the lack of water, what damages agricultural activities, specifically the subsistence agriculture [2]. Forage palm is a cactus that is adapted to the climate conditions of the semiarid due to its morphologic characteristics, among them are the biological processes that enable absorbed water economy, thus having an elevated socioeconomic potential to the region where it is cultivated. However, its exploration is basically related only to feed livestock during droughts [3].

According to literature the potential for the usage of forage palm goes beyond animal feeding, as it can be directly related to intensive business in knowledge to which great value is added, such as medication destined to treating widespread diseases, such as gastritis, hyperglycemia, diabetes, arteriosclerosis, or even prostatic hypertrophy [4].

Since it is rich in vitamins, minerals and many kinds of amino acids, the palm became a viable food source, being in some cases more nutritious than foods such as kale, beet, and bananas. In Brazil, despite having nutritious and economic qualities there is still a prejudice towards eating this vegetable. However, in countries such as Mexico, The United States of America and Japan, the palm is seen as a noble food, being served in luxury hotels and restaurants [5]. The palm cladodes are used in recipes, fresh or processed [6].

Brazilians' eating habits is changing, related to having less free time to cook and to the desire for a better life quality, making people look for healthier food, which increases the consumption of fruits and fresh plants, which are readily available. Minimal processing comes supplies this demand, providing fresh products that are sent to the shelves clean, in a convenient manner, and are also quickly prepared and eaten, giving to these products a higher added value, in addition to a better production use, reduction of post-harvest loss and a better waste efficiency [7].

Minimally processed foods are generally fruits or vegetables that are chopped and are kept fresh and ready to eat for a long time with a superior standard [8]. For this purpose, the steps in processing are essential to a quality palm use,

making it easier and enhancing its appearance, accordingly to the people's demand. Therefore, minimal processing is an innovation tool, since it makes handling and eating this non-conventional plant an easier task [9]. It was aimed to assess the physical-chemical quality of young cladodes of the Mexican elephant ear' palm, while minimally processed over the course of 10 days of storage.

2. MATERIALS AND METHODS

2.1 Plant Material Selection

There were used young palm cladodes of the plant 'Mexican elephant ear' *Opuntia tuna* (L.) Mill. from tertiary order (young cladodes articulated to the secondary cladode) and quaternary (young cladodes articulated to the tertiary cladode) with 30 days of age (the choice for younger cladodes is due to the fact that their leaf tissue is softer, as it contains less fibers)and ranging from 14 to 20cm in length. 5.86 kg of total fresh mass were manually harvested with knives, early in the morning from 6:30 AM to 7:30 AM with a good appearance and characteristic color.

2.2 Minimal Processing

Young cladodes were conditioned in polystyrene trays and transported to the Chemistry, Biochemistry and, Food Analysis Laboratory of the Agrifood Science and Technology Center, Pombal campus (Fig. 1A), where they were washed in running water to remove excess field residues. In the laboratory, a cold bath was prepared in a tray with 9L of mineral water and 2kg of ice, in which the cladodes were submerged for 5 minutes, aiming to remove the heat from the field and lower sprout metabolism to diminish stress due to the sudden change in temperature (Fig. 1B).

With the aid of stainless steel knives the thorns and deformed young cladodes were removed, right after the cladodes were sorted by size (Fig. 1C). Minimal processing was done with robotcoupe (CL 50 ultra) using a 2 mm blade and retractor (Fig. 1D). Young cladodes were put in longitudinal direction with peduncle pointing upward, to obtain processed, transversal cuts (Fig. 1E), irregular pieces were discarded. After processing, the young cladodes were conditioned in expanded polystyrene trays, and wrapped in a 12μm PVC film layer, containing approximately 90 g of young cladodes, and kept at 4±1°C and 40±5% RH, over the course of 10 days.

2.3 Trial Design

The used trial design was the completely randomized design (CRD), to the "Mexican elephant ear" plant, consisting in 6 treatments in five repetitions, being considered a treatment the days of analysis during storage (0, 2, 4, 6, 8 and 10).

2.4 Physical-chemical Analysis

To the physical-chemical analysis, it was necessary to obtain the cell extract of the palm sprouts was needed. To do so, the sprouts were blended in a domestic blender with water added to the 1:1 (mass: volume) proportion and the obtained extract was graded through the following parameters:

- Fresh mass (%): it was gravimetrecally quantified as young cladodes conditioned in polystyrene trays and PVC film was weighted in a precision scale with 0.01g accuracy. Obtained masses were transformed to loss of fresh mass percentage, having the mass on the first day of analysis as 100%.
- Soluble solids (%): juice was filtered through a layer of cotton and the soluble solids content was read in a digital refractometer with automatic temperature compensation.
- HIdrogenionic Potential (pH): was determined with a bench digital potentiometer, being the reading realized through the electrode's direct immersion. The concentration of H^+ ions was estimated through the equation: pH = - log $[H^+]$.
- Titratable Acidity (malic acid %): was measured in 1ml of juice, made homogeneous in 49mL of distilled water. The solution containing the sample was titrated with NaOH 0.1N until the turning point of the phenolphthalein indicator, confirmed by the pink-hued coloration. Total titratable acidity was expressed as a percentage of acid abundant in the palm equivalent to the amount of NaOH 0.1N used in the titration according to the Analytic Norms of Instituto Adolfo Lutz [10].

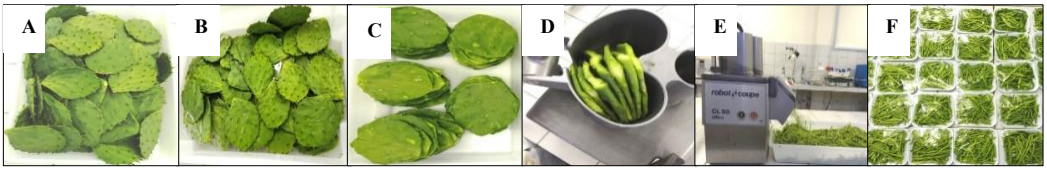

Fig. 1. Steps in minimal processing of young cladodes of the 'Mexican elephant ear' palm

- Soluble Solids and Titratable Acidity Ratio (SS/TA): obtained by dividing the soluble solids value by the values of titratable acidity.
- Ascorbic Acid (mg/100 g): The value of ascorbic acid was estimated through titration, being utilized 5.0ml of cell extract from the young palm cladodes, added of 45ml of oxalic acid 0.5% and titrated against Tillmans Solution (2.6 dichlorophenolindophenol 0.2%) 0,2until the pink coloring, according to the Instituto Adolfo Lutz method [10].
- Phenolic Compounds (mg/100 g): were estimated using the Folin-Ciocalteu method [11], through the mixture of 25 µL of filtered palm juice with 1.575µL of distilled water and 100 µL of the Folin-Ciocalteu reagent, followed by agitation and rest for 5 minutes. The standard curve was prepared with gallic acid and readings were done in a spectrophotometer at 765 nm.
- Chlorophyll and carotenoids (mg/100 g e µ/100 g): were determined according to Lichtenthaler [12]. About 0.2g of the juice was mixed with 0.2g of calcium carbonate and 5ml acetone (80%) kept in a cold, dark place. After that, the samples were centrifuged at 10 °C and 3.000 rpm for 10 minutes and the supernatant were read in a spectrophotometer in the absorbance of 470, 646 e 663 nm.

2.5 Statistical Analysis

Data obtained was subject to variance analysis through the AgroEstat® software and the means compared through Tukey test, at a 5% probability level, as the correlation analysis between the variables [13].

3. RESULTS AND DISCUSSION

To the fresh mass loss in young cladodes of the 'Mexican elephant ear' minimally processed, the values diverged, with the exception of the values 0 and 2 for time, that were statistically equal (Fig. 2A). It's also noted an accumulation of fresh mass loss during the 10 days of storage. This accumulation can be linked to low humidity to which the product was exposed. It's observed that even storing the minimally processed young cladodes in a polystyrene tray wrapped in PVC film there was a loss of mass of the product. This behavior was already expected, bearing in mind that the cuts increase the transpiratory rate of the tissues. Pereira et al. [9] that studied post-harvest quality and minimal processing of young cladodes of the *Opuntia ficus-indica* Mill palm and found an increase in fresh mass loss related this event.

In the soluble solids content, there was a significant alteration as for days of storage, ranging from 3.1 and 3.6%, respectively (Fig. 2B). Differently from that found by Silva et al. [14] when studied about physical and chemical characteristics of giant and small palms, and found the value of 6.60% to soluble solids in the 'giant' palm in that study whole cladodes were used. The difference among the soluble solids contents could be related to factors such as: studied plant, size of young cladodes and minimal processing, bearing in mind that according to Pinelli [15] mechanical stress during processing results in accelerated metabolism, being the starch converted to sugar, which is consumed in the metabolic processes.

It was observed that the hydrogenionic potential of young palm cladodes diverged statistically with the values ranging from 3.5 to 3.9 (Fig. 2C). In the study of Silva et al. [14] when assessing the physical and chemical characteristics of the 'giant' and 'small' palms obtained a mean of 4.4 to the young 'giant' palm cladodes. It can be assumed that the variation is linked to the alterations between the plants, and to the fact that in the work there were not used minimally processed young cladodes. On the other hand, the values found in the present paper match Pereira et al. [9] that studied post-harvest quality and minimal processing of young cladodes of the *Opuntia ficus-indica* (L.) Mill. palm, that obtained results around 3.5, is a positive characteristic, seen that acidic pH is a limiting factor to deterioration and microbial development.

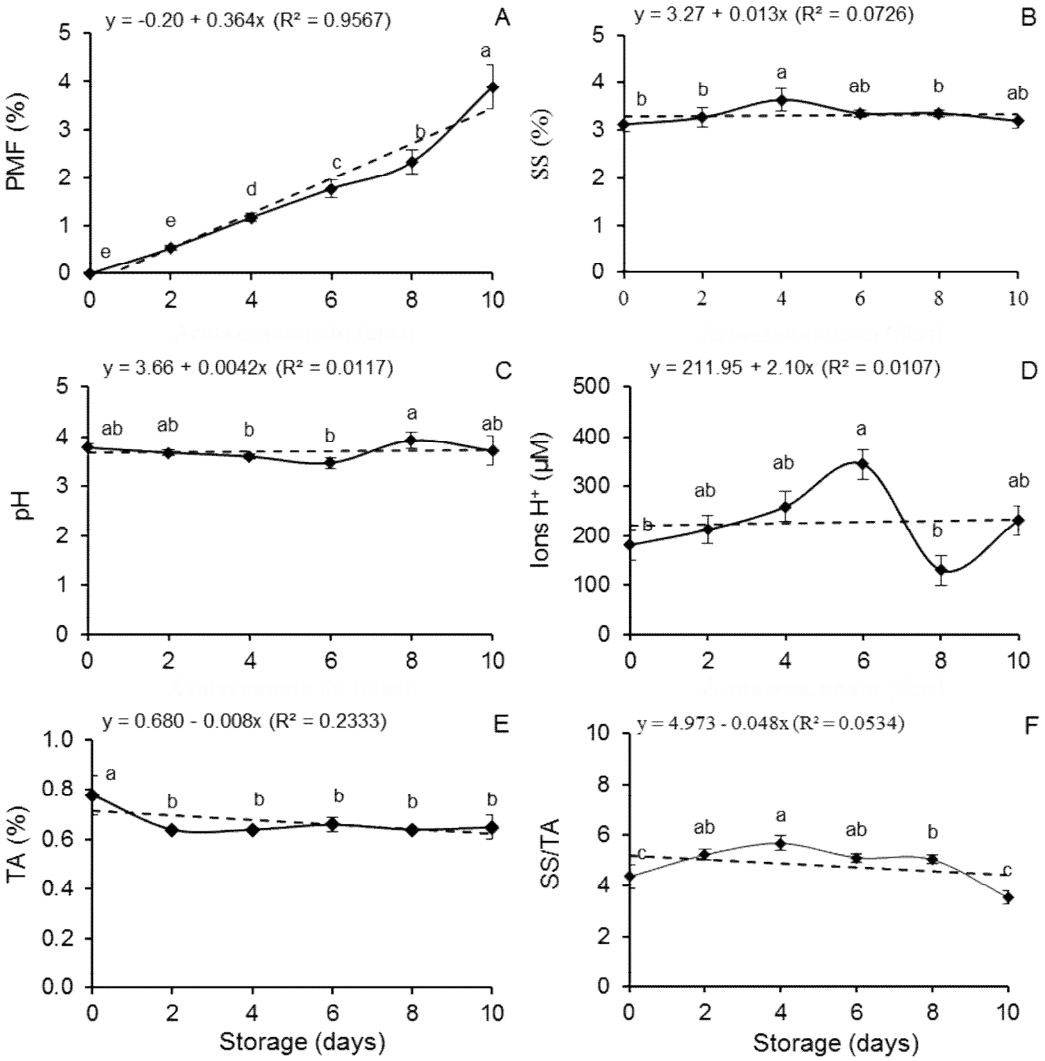

Fig. 2. Loss of fresh mass (A), soluble solids (B), hydrogenionic potential (C), H^+ ion concentration (D), titratable acidity (E) and soluble solids and titratable acidity ratio (SS/TA) in minimally processed young cladodes of the 'Mexican elephant ear' palm

There was a significant difference in the concentration of hydrogen ions (Fig. 2D) with a variance of 129.7 to 344.4µM through storage. These results differ from the ones found by Farias [16] when determined the quality of young palm cladodes of the 'giant' plant without minimal processing, obtained values ranging from 25.8 to 209.8µM identifying an increase in the hydrogen ions concentration.

As for the titratable acidity content, there was a significant difference between treatments, but the values ranged from 0.6 to 0.8% there having a significant similarity until the last day of storage (Fig. 2E). This behavior supports the value reported in the work of Lima et al. [17], that studied post-harvest quality in young cladodes of alterations palm plants, and verified that the 'elephant ear' palm had values close to 0.5%.

The soluble solids and titratable acidity ratio showed significant differences, there is a variation from 3.5 to 5.7 (Fig. 2F). According to Farias [16] the SS/TA ratio has been used as a diagnosis factor in a food's taste. Milder tastes happen when the ratio value is elevated and acidic tastes when lower values are found. Results obtained in this work suggest that young cladodes between times 2 and 4 would provide a more pleasant taste when compared to the others.

There were no significant correlations observed between loss of fresh mass and the remaining characteristics assessed. (Chart 1). There was an intense negative correlation between pH and hydrogen ions content, given the fact that the H^+ ion concentration is inversely proportional to pH.

Soluble solids/titratable acidity ratio correlated positively to soluble solids and negatively to titratable acidity, what shows that this reason is influenced mainly by the soluble solids content. Remaining physical-chemical characteristics did not show any significant correlation between them.

A significant reduction in the presence of ascorbic acid over storage was (Fig. 3), ranging from 0.1 to 0.3 mg/100 g. This interval coincides with the value found by Lima et al. [17] when the *Opuntia tuna* (L.) Mill palm was studied for the post-harvest quality in young cladodes of different palm plants; a value of 1.6mg/100 g was measured. According to Chitarra and Chitarra [18] the decrease in ascorbic acid is due to the

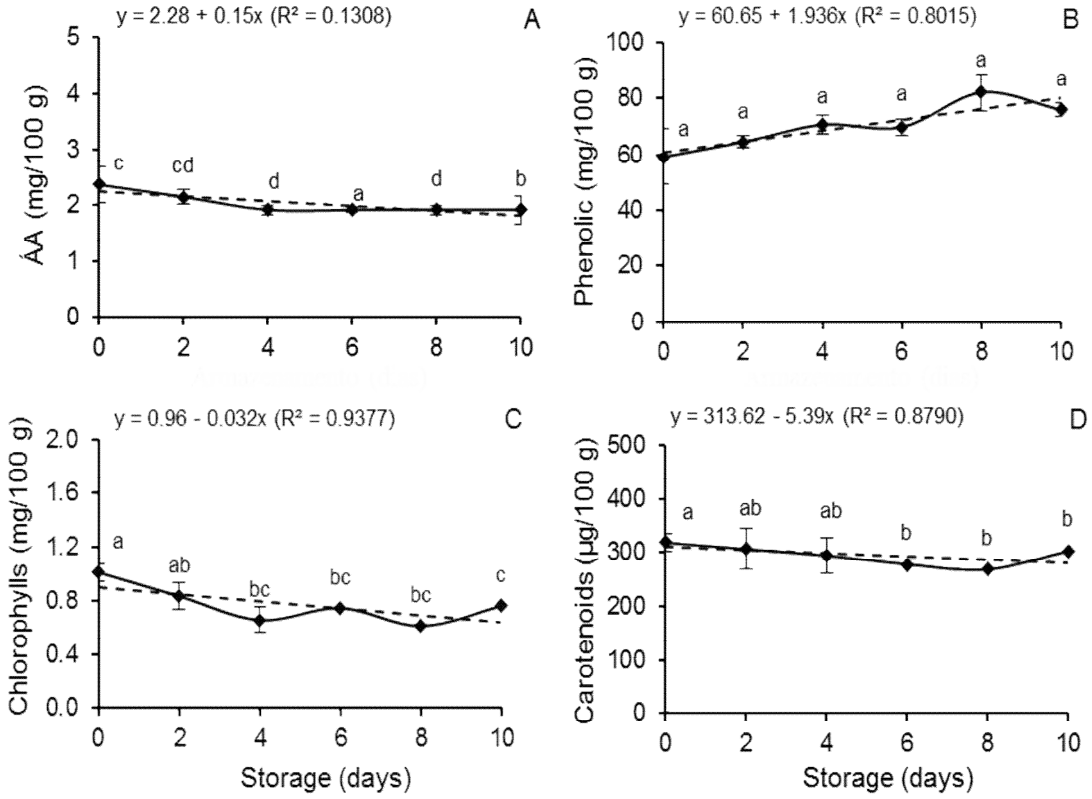

Fig. 3. Ascorbic acid (A), phenolic compounds (B), chlorophylls (A) and carotenoids (B) in minimally processed young cladodes of the 'Mexican elephant ear' palm

Chart 1. Analysis chart of correlation between physical-chemical characteristics of minimally processed young cladodes of the 'Mexican elephant ear' palm

Characteristics	LFM	HP	H^+	SS	TA
HP	0.0836^{NS}	-	-	-	-
H^+	0.0359^{NS}	-0.9441**	-	-	-
SS	0.1846^{NS}	-0.4827**	0.4896**	-	-
TA	-0.3116^{NS}	0.0282^{NS}	-0.0656^{NS}	-0.2960^{NS}	-
SS/AT	-0.3520^{NS}	-0.2260^{NS}	0.2016^{NS}	0.5149**	-0.5525**

***: significant; NS: Non-significant; LFM: loss of fresh mass; SS: soluble solids; TA: titratable acidity; SS/TA: soluble solids and titratable acidity ratio; HP: hydrogenionic potential; H^+: hydrogen ions concentration.*

Chart 2. Analysis chart of correlation between the characteristic of bioactive compounds in minimally processed young cladodes of the 'Mexican elephant ear' palm

Characteristics	Ascorbic acid	Total chlorophyll	Total carotenoids
Total chlorophyll	-0.3477^{NS}	-	-
Total carotenoids	-0.3464^{NS}	0.6895**	-
Phenolic compounds	-0.0018^{NS}	-0.5471**	-0.3633*

***: significant; NS: Non-significant.*

development of vegetables what can be a responsible factor in the apparent decrease in the first days of storage in this study. Pereira et al. [9] who studied the post-harvest quality in minimal processing of young cladodes of the *Opuntia ficus-indica* (L.) also reported this fact. Mill. palm, and obtained a reduction in content starting on the fourth day of storage.

There was a significant difference for the phenolic compounds (Fig. 3B), with values ranging from 27.9 to 82.1mg/100 g over the course of storage. Differently from the value interval found by Formiga et al. [19] that assessed the 'Mexican elephant ear' palm for the characterization of bioactive compounds, in Young cladodes of palm in different stages of development and obtained values ranging from 34.28 e 54.84mg/100 g, individually. This difference may be related to the maturing stages of young cladodes

In the chlorophyll Content, it was observed that there was a significant difference between the days of storage (Fig. 3C). Values ranged between 0.65 to 1.01mg/100 g, being smaller than the ones found by Farias [16] who determined the quality and antioxidant capacity in young palm cladodes and obtained values between 1.03 and 2.44mg/100 g. This decrease could be linked to minimal processing. According to Silva et al. [20] identifying loss of chlorophyll is a characteristic of the utmost importance to the quality of the minimally processed product during its marketing.

During storage, a significant difference was diagnosed in the carotenoid content (Fig. 3D), ranging between 278 and 318 µg/100 g, this interval coincides with the value found by Lima [21], who assessed bioactive compounds in young cladodes of the 'Gialla' palm and obtained values of 303.80 µg/100 g. It is noticed that the content found in this work is close to the one reported in the literature, supporting the presence of carotenoids the minimally processed palm. According to Durigan [22], carotenoids are noteworthy once they contribute to the maintenance of human health, preventing diseases, acting against free radicals and reinforcing resistance.

There was no significant correlation between the ascorbic acid and total chlorophyll variables, as well as the total carotenoids (Chart 2). Phenolic compounds on the other hand correlated weakly and negatively to total chlorophyll and carotenoids.

4. CONCLUSION

Palm can be used in many ways, and can be included in human diet due to its nutraceutical properties. To enable palm's consumption as an edible plant, minimal processing is of utmost importance, as, it added value to the product and facilitates its marketing. The quality of minimally processed young cladodes was not altered during storage, so it acts as an alternative.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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