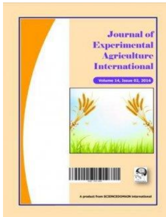

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Physiology and Postharvest Quality of Palm Sprouts (*Opuntia fícus-indica*) Harvested at Different Times

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Authors' contributions

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

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ABSTRACT

Objective: The study aims to evaluate the physiological and postharvest quality characteristics of the palm (*Opuntia fícus-indica*) sprouts harvested at different times.
Experimental Design: The experiment was laid out in a completely randomised design, consisting of three palm cultivars (Gigante, Clone IPA 20 and Redonda) and eight harvest times (3, 6, 9, 12, 15, 18, 21 and 24 hours).

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Place and Duration of the Study: Experiment was carried out in the experimental area of the Agri-Food Science and Technology Center of the Federal University of Campina Grande, Pombal, Paraíba, from November to January 2016.
Methodology: The experiment was carried out in a completely randomised design (CRD), in a factorial scheme of 8x3x3, having 8 harvest times (3, 6, 9, 12, 15, 18, 21 and 24 hours), 3 cactus cultivars ("Gigante", "Clone IPA 20" and "Redonda") and 3 replicates, belonging to the family Opuntia.
Results: Sprouts of "Gigante" presented the highest values of titratable acidity, ascorbic acid and chlorophyll. The average titration value of 0.63 (% malic acid), 11.2 mg ascorbic acid , and 1320.8 μg chlorophyll 100^{-1} of fresh mass, were observed in 3, 6 and 9^{th} hours of harvest. After these periods, a significant loss of these compounds were recorded.
Conclusion: 'Gigante' cultivar presented the best performance for the evaluated parameters. Palm sprouts showed a high values of titratable acidity, ascorbic acid, chlorophyll and phenolic compounds. Different harvesting schedules influenced the quality of these parameters. Based on the physiological characteristics evaluated, it has been revealed that the best harvest periods are 3, 6 and 9 hours.

Keywords: Opuntia fícus-indica; harvesting interval; ascorbic acid; phenolics.

1. INTRODUCTION

Palm (*Opuntia fícus-indica*) is a widely used crop in the world, with special emphasis on the use of bases for the production of cosmetics and pharmaceuticals.

Palm sprout (young cladodes) is seen as a herb of the desert and several recipes are made with this herb, both sweet or salty dishes. The palm sprouts are composed of 92% water, 4% total carbohydrates, 4% fibre, 1% protein, minerals such as calcium (1%) and potassium (166 mg 100 g^{-1}), 10 to 15 mg 100 g^{-1} of vitamin C and 30 mg 100 g^{-1} of carotenoids [1]. The sprouts also comprised of flavonoids such as kaempferol, isoramino and quercetin in the form of aglycones,i.e., molecules without sugars [2,3].

Several factors must be taken into account for its physiology as the plant has a characteristic cactaceae metabolism. Crassulacean Acid Metabolism (CAM) resulted the rusticity and resistance to water stress that directly interfere the taste as the acidity and its pH, leading to variation throughout the day, besides its high productivity when compared with species C3 and C4 plants [4]. The knowledge of the time of harvest of the palm shoot would allow to know its quality throughout the day.

The palm sprout is shown as a potential alternative in Northeastern Brazilian cuisine, comprising of several sophisticated dishes attracting several consumers. Many species are used for these purposes, among the most common in the northeast region, the study highlights the cultivars 'Gigante', 'Clone IPA 20' and 'Redonda'. Therefore, the study aims to evaluate the postharvest physiological quality of palm sprout (Gigante, Clone IPA20 and Redonda) harvested at different times.

2. MATERIALS AND METHODS

2.1 Plant Material

Sprouts of "Gigante" (BPG), "Clone IPA 20" (BPI) and "Redonda" (BPR) cultivars were collected from the experimental zone, belonging to the Center of Science and Technology of the UFCG, Câmpus Pombal, located in Pombal-PB, Brazil (Latitude: 06º46' 13" S and Longitude: 37º48' 06" W), classified as BSh (hot semi-arid climate) [5].

2.2 Methodology

Sprouts were harvested in 10-15 cm long, starting at 3 o'clock in the morning and ending at 24 o'clock in the next day with an interval of 3 hours, totalling of 8 harvests with three replicates each. After the harvest, the shoots were transported to the "Food Analysis Laboratory" where they were washed, dried and subsequently subjected to the following analysis.

2.3 Analytical Determinations

Soluble solids (SS): The cell juice was extracted from 100 g of palm sprouts, crushed with the aid of a cell juice extractor. The soluble solids content was measured in a digital refractometer with automatic temperature compensation.

H^+ ion content: Hydrogen ionic (H^+) potential was determined according to the number of repetitions using a digital bench potentiometer.

Titratable Acidity (TA): The acidity was measured in 5 ml of juice, homogenised in 45 ml of distilled water. The solution containing the sample was titrated with 0.1 N NaOH until reaching the turning point of the phenolphthalein indicator, confirmed by the indicator pH range of 8.2 [6].

Ascorbic Acid (AA): Ascorbic acid was estimated by titration method using 5 ml of palm juice and 45 ml of 0.5% oxalic acid and titrated with Tillmans solution until reaching pink staining according to the method (365/IV) [7].

Pigments: Chlorophyll contents were estimated by using the standard protocol of Lichtenthaler [8]. The chlorophyll and carotenoid contents were defined from the following equations:

Chlorophyll a (mg $100g^{-1}$ Fresh mass) = 12.25 $A_{663.2}$ - 02.79 $A_{646.8}$

Chlorophyll b (mg $100g^{-1}$ fresh weight) = 21.5 $A_{646.8}$ - 05.1 $A_{663.2}$

Total Chlorophyll (mg $100g^{-1}$ Fresh Mass) = 07.15 $A_{663.2}$ + 18.71 $A_{646.8}$

Carotenoids (mg $100g^{-1}$ Fresh Pasta) = (1000 A_{470} - 1.82 C_a - 85.02 C_b)/198

Total sugars: To estimate total sugar content, about 0.5 g of palm sprout was macerated in 10 ml of distilled water, and the volume was made up to 50 ml. An aliquot of 400 ml of the diluted extract, 1000 ml of distilled water and 1000 ml of Anthrone were used for reaction in boiling water for 10 minutes followed by a cooling in ice water to room temperature. The determination process of soluble sugars were performed at 620nm in SP-1105 spectrum [9].

Phenolic compounds: Phenolic compounds were estimated as per the method of Folin and Ciocalteau with modifications [10]. An aliquot of 500 µl of the extract was transferred to a test tube and mixed with 1625 µl of water and 125 µl of the Folin-Ciocalteau reagent. The mixture was allowed to incubate for 5 minutes, and then added 250 µl of 20% sodium carbonate, followed by stirring and incubated in a water bath at 40°C for 30 minutes. The results were shown as mg of gallic acid 100 g^{-1} FM.

2.4 Statistical Analysis

The experimental design was in a completely randomised design (CRD), in a factorial scheme of 8x3x3, having 8 harvest times (3, 6, 9, 12, 15, 18, 21 and 24 hours), 3 cultivars (BPG, BPI and BPR) and 3 replicates.

Statistical analysis was carried out to test the analysis of variance (ANOVA), using AgroEstat software, version 2014 [11]. The means were compared by the Tukey test with 95% probability level ($P \le 0.05$). When significant differences were found, regression analysis was performed.

3. RESULTS AND DISCUSSION

3.1 Soluble Solids (SS)

SS values varied from 4.4 to 7.5% for BPG, from 3.8 to 5.8% for BPI and from 3.8 to 5.2 for BPR. These values can be explained as response to plant metabolism to the environment and harvest time. No statistical difference ($P>0.05$) was observed in the soluble solid content in the palm sprouts (Fig. 1).

Several researchers confirmed the variation of SS content in the palm sprouts with a values around 2 to 8% [12,13]. These variations recorded in the SS content of the shoots could be linked to the energy consumption of the plant during the photosynthetic process [14].

3.2 Concentration of H^+

There was a possibility to establish a functional relationship between the H^+ ion content in BPG and BPI,with a progressive decrease to 15 hours (Fig. 2). No statistical differences ($P> 0.05$) was recorded for the H^+ ion content of BPR with an average value of 10.22.

These values were found to be consistent with the synthesis and consumption of acids throughout the day, as can be seen in Fig. 3, where the highest and lowest TA peaks are at the same harvest times. Farias [15] reported that shoots at different stages of development (harvested around 9 am) showed the values of 25.8 to 209.8 µM for BPG and 19.61 to 95.86 µM in BPR.

3.3 Titratable Acidity (TA)

A functional relationship was established between the titratable acidity content only in the BPI (Fig. 3). However, all cultivars showed a progressive decrease in titratable acidity values up to the 6 harvests (18 hours). No statistical differences (P> 0.05) were recorded for TA for BRG and BPR with a mean values of 0.63 and 0.60 (% malic acid). Corrales-García et al. [16] studied 10 cultivars of palm where acid contents varied from 0.28 to 0.76% in shoots at 30 days of age and 20 cm in length, collected at 6 hours period.

The acid behaviour described in this study can be attributed to plant age and management, as well as the acidic metabolism of this cactus. It has been found that the acid content in the palm (*Opuntia fícus-indica*) in natura varies according to the size of the cladodes, management conditions and stage of development [17]. The variation of the acidity during the day is a typical characteristic of CAM plants and it must be taken into account to determine the harvesting time [18].

3.4 Ascorbic Acid (AA)

There was a significant effect (P> 0.05) for ascorbic acid in BPG and BPR, with the best fit for the quadratic equation, with values ranging from 0.9 to 12.5 and 2.5 to 9.1 mg 100^{-1} fresh mass respectively (Fig. 4). For BPI, no significant effect (P> 0.05) was observed, with a mean value of 3 mg 100^{-1}g of fresh mass.

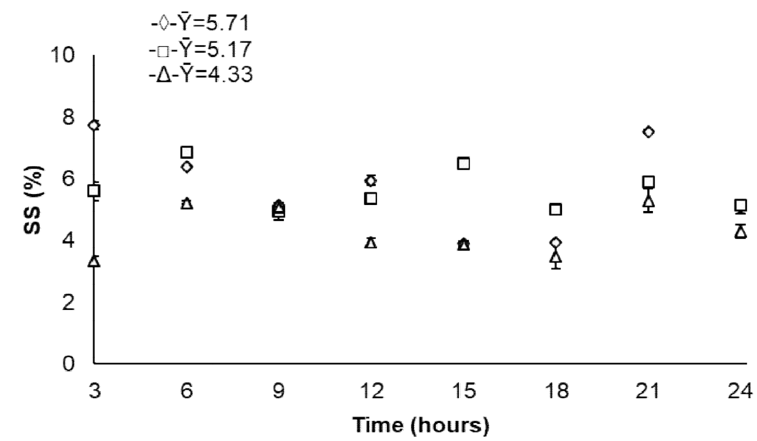

Fig. 1. Soluble solids in BPG (-◊-), BPI (-□-) and BPR (-Δ-). The vertical bar represents the standard deviation of the mean

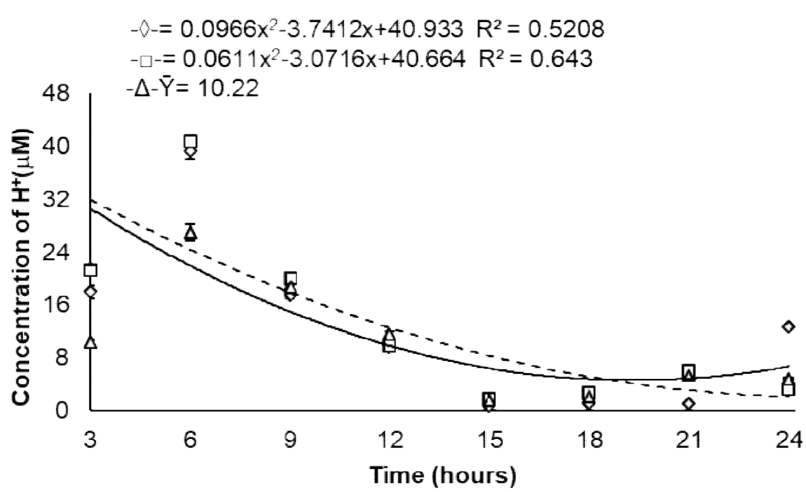

Fig. 2. Concentration of H^+ in BPG (-◊-), BPI (-□-) and BPR (-Δ-). The vertical bar represents the standard deviation of the mean

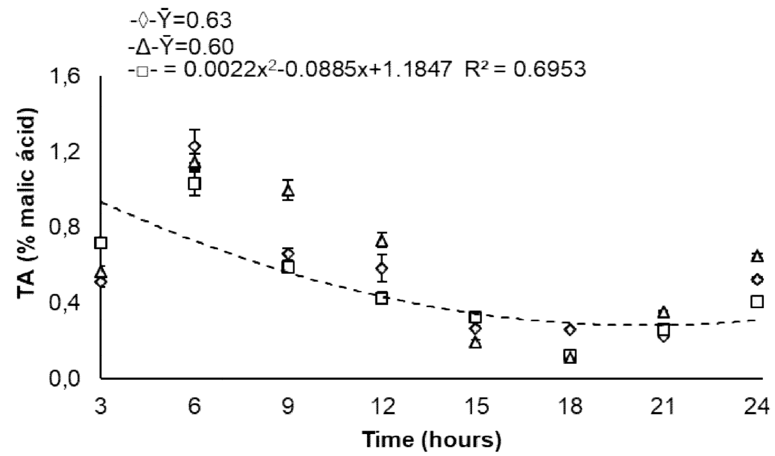

Fig. 3. Titratable Acidity in BPG (-◊-), BPI (-□-) and BPR (-Δ-). The vertical bar represents the standard deviation of the mean

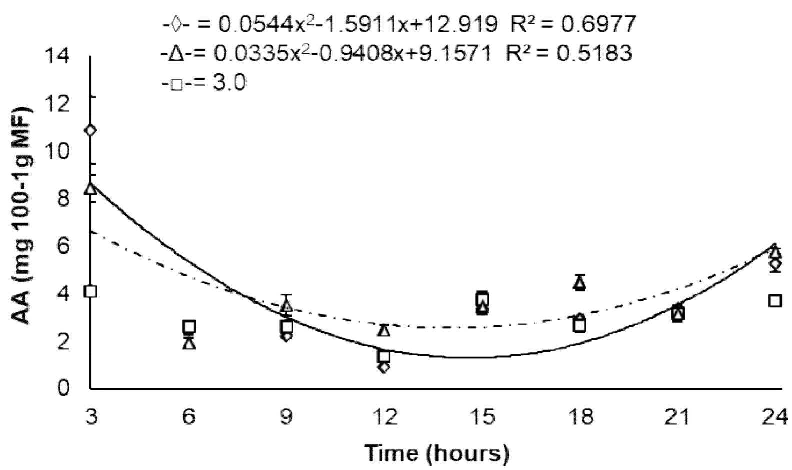

Fig. 4. Ascorbic Acid in BPG (-◊-), BPI (-□-) and BPR (-Δ-). The vertical bar represents the standard deviation of the mean

The variations of ascorbic acid levels were found during the harvest times might be attributed to the consumption of this antioxidant in synthesis of biochemical reactions [15]. The recorded vitamin C content in BPR and BRG ranged from 10 to 18.1 mg $100g^{-1}$ palm sprouts [1].

3.5 Pigments

No significant effects were observed (P>0.05) for chlorophyll total (CT) content in BPG, BPI and BPR, with mean values of 1320.8, 1296.9 and 1333.3 μg 100^{-1}g fresh mass (Fig. 5).

A significant effect (P> 0.05) was observed for the carotenoid content in BPG, with the value ranging from 721.4 to 1754.16 μg 100^{-1}g in fresh mass. However, no significant correlation was recorded for BPI and BPR with a mean value of 208.7 and 211.1 μg 100^{-1}g of fresh mass, respectively (Fig. 6).

The pigments assist in the photosynthetic process besides presenting anticarcinogenic and antioxidant action. The high values of chlorophyll recorded in this study prove the beneficial action of this desert vegetable in the human diet [15,18]. The values are consistent with this work evaluating the quality of young and fresh palm sprouts.

3.6 Soluble Sugar

No significant correlation (P>0.05) was recorded for the soluble sugars content in BPG, BPI and

BPR, with mean values of 1.29, 1.34 and 0.86 g 100^{-1} g fresh mass, respectively (Fig. 7).

The values of soluble sugars presented the highest levels (12 hours), and this behaviour might be attributed to a physiological response as a function of the time, since the 4^{th} harvest corresponds to the highest temperature schedule of the day. The total sugar values for BPG were 1.28-2.16 mg $100g^{-1}$ and 1.53- 2.90 mg $100g^{-1}$ in BPR, which corroborates with the earlier study [19] .

3.7 Phenolic Compounds (PC)

No statistical significance (P> 0.05) was observed for the content of phenolic compounds in BPG, BPI and BPR, with mean values of 139.8, 142.8 and 101.4 mg of gallic acid 100^{-1}g of fresh mass, respectively (Fig. 8).

The phenolic compounds are stable during processing under high temperature conditions, therefore, for increased phenolic compounds increased levels may occur due to the breakdown of cellular constituents [20]. This variation of phenolic compounds might be attributed to enzymatic reactions of synthesis and degradation during the acid metabolism of this desert vegetable.

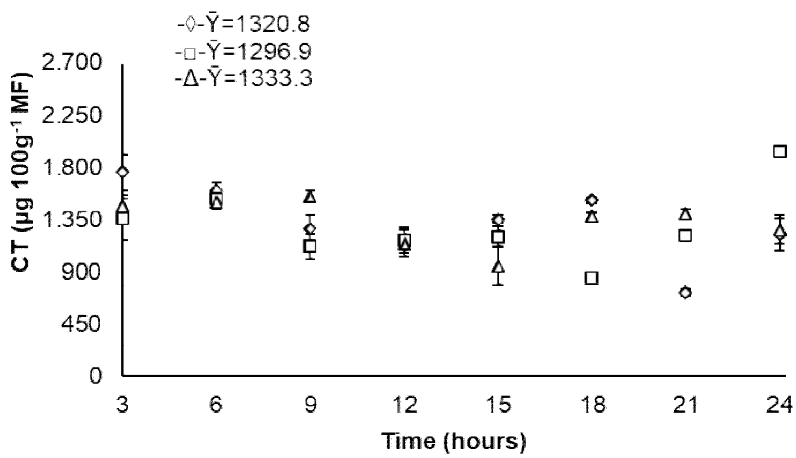

Fig. 5. Chlorophyll total in BPG (-◊-), BPI (-□-) and BPR (-Δ-). The vertical bar represents the standard deviation of the mean

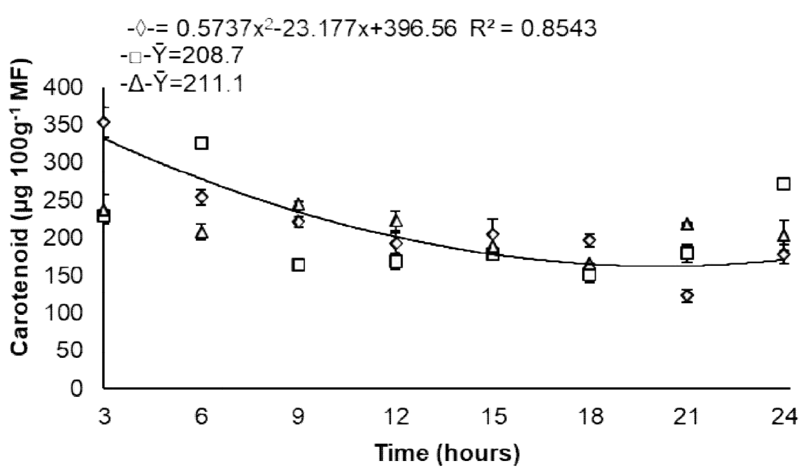

Fig. 6. Carotenoid total in BPG (-◊-), BPI (-□-) and BPR (-Δ-). The vertical bar represents the standard deviation of the mean

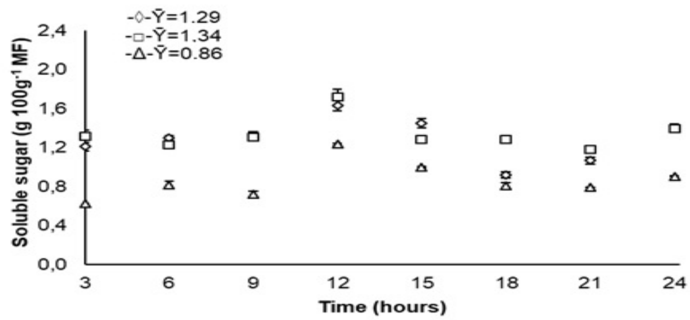

Fig. 7. Soluble sugar in BPG (-◊-), BPI (-□-) and BPR (-Δ-). The vertical bar represents the standard deviation of the mean

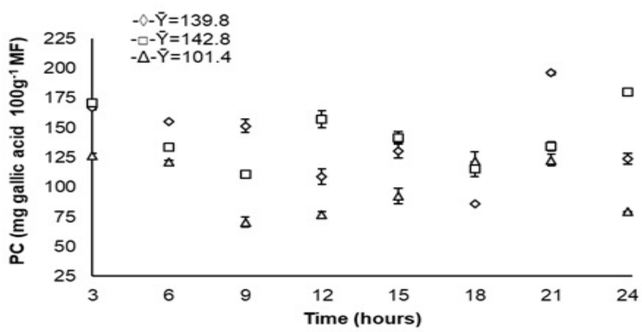

Fig. 8. Phenolic compounds in BPG (-◊-), BPI (-□-) and BPR (-Δ-). The vertical bar represents the standard deviation of the mean

The PC levels of 910 mg 100 g^{-1} in crisp lettuce and 900 mg 100 g^{-1} in arugula, when grown under conventional production system were reported by Arbos et al. [21]. This distinction between PC values might be attributed to climate and species differences when compared to palm sprouts.

4. CONCLUSION

It is concluded that, 'Gigante' cultivar (BPG) can be considered as a source of best palm sprout for performing optimum values towards almost all measured quality parameters. Palm sprouts (BPG, BPI and BPR) have showed high values of titratable acidity, ascorbic acid, chlorophyll and phenolic compounds at 3, 6 and 9 hours of harvesting period. The high concentration of phenolic compounds indicates that BPG, BPI and BPR have antioxidant power acting in preventing disease. The values of soluble sugars are considered satisfactory for a vegetable and harvest schedules have influenced the quality of this plant. The best harvest dates are 3, 6 and 9 hours, based on the physiological characteristics evaluated.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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