Cold storage of juçara (*Euterpe edulis* Martius) fruits: stability of the bioactive compounds and antioxidant activity

Armazenamento à frio de frutos de juçara (*Euterpe edulis* Martius): estabilidade de compostos bioativos e atividade antioxidante

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**ABSTRACT**

*Euterpe edulis* Martius, known as juçara, is a palm tree threatened with extinction. The sustainable use of its perishable fruits, a promising source of bioactive compounds, would help to preserve this plant. In this study the authors evaluated the effect of temperature and storage time on the physicochemical, microbiological and colorimetric characteristics and on the bioactive compounds of the juçara. Major changes were found in the physicochemical and microbiological characteristics of the fruits stored at 5 °C and at 25 °C for 14 days, but fruits stored at -18 °C maintained most of their characteristics throughout 180 days. The bioactive compound was maintained, the antioxidant capacity increased (61%) and the coliform count reduced during this period. The results showed that juçara fruits frozen could be stored for up to 6 months, which is important in order to overcome problems related to the seasonality and short harvesting period of this fruit.
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Keywords: phenolic compounds, antioxidant activity, cold storage, anthocyanin, tropical fruit

RESUMO

*Euterpe edulis* Martius, conhecida como juçara, é uma palmeira ameaçada de extinção. O uso sustentável de seus frutos perceríveis, uma fonte promissora de compostos bioativos, ajudaria na preservação desta espécie vegetal. Neste estudo os autores avaliaram o efeito da temperatura e do tempo de armazenamento nas características físico-químicas, microbiológicas, colorimétrica e nas características bioativas dos frutos de juçara. As principais mudanças nas características físico-químicas e microbiológicas foram encontradas nos frutos armazenados a 5 °C e 25 °C por 14 dias, porém os frutos armazenados a -18 °C mantiveram as características ao longo de 180 dias. Os compostos bioativos foram mantidos, a capacidade antioxidante aumentou (61%) e a contagem de coliformes reduziu durante este período. Estes resultados mostraram que os frutos de juçara congelados foram armazenados por até 6 meses, o que é importante com o objetivo de superar problemas relacionados com sazonalidade e curto período de colheita deste fruto.

Palavras-chave: compostos fenólicos, atividade antioxidante, armazenamento sob refrigeração, antocianinas, fruto tropical

1 INTRODUCTION

*Euterpe edulis* Martius, popularly known as the juçara palm tree, is a palm tree native to the Atlantic Forest, with a coastal geographic distribution from the south of the state of Bahia to the north of the state of Rio Grande do Sul in Brazil (REIS et al., 2000).

Juçara palm fruits have many properties of benefit to the health associated with the presence of bioactive compounds, especially anthocyanins (SILVA et al., 2014; PEREIRA et al., 2018). Many factors influence the stability of anthocyanins, such as temperature, oxygen, light, solvent concentrations, ascorbic acid, sulfur dioxide, the presence of enzymes such as peroxidase, polyphenol oxidase and glycosidase, metal ions, sugars, proteins, minerals and other flavonoids (SCHWARTZ et al., 2008). In foods, it has been noted that processing and storage interfere with the stability of these compounds (PEREIRA et al., 2016; PEREIRA et al., 2017).

The low stability of the bioactive compounds is a barrier to the processing of juçara palm fruits. Another difficulty encountered for the use of these fruits is their seasonality, with a high production during a short period of time. To overcome these limitations, a better understanding concerning the stability of these fruits when stored under freezing or refrigerated conditions, is required.

Freezing is characterized by reducing the food temperature with the formation of ice crystals, increasing its shelf life by reducing the water activity (REQUE et al., 2014). Refrigeration, on the other hand, corresponds to the reduction in temperature of the food to between -1 and 8 °C in order to reduce the microbiological and enzymatic activities (TOLEDO, 2007), thus prolonging the shelf life by days or weeks. Both preservation methods can be used by juçara fruit processing industries, but there are few studies on the stability of the product during storage.
The objective of this study was to evaluate the physicochemical, microbiological and colorimetric characteristics and the bioactive compounds of *Euterpe edulis* Martius fruits stored for 14 days at a room temperature of 25 °C, under refrigeration at 5 °C, and frozen at -18 °C. The same characteristics were also evaluated for fruits maintained frozen at -18 °C for 6 months.

2 MATERIAL AND METHODS

This study was developed in the Department of Food Science and Technology of the Federal Institute of Education, Science and Technology of Southeast Minas Gerais (IF Sudeste MG), at its Rio Pomba campus, in partnership with The Kaufmann Food Company. The juçara fruits were acquired from producers in the municipality of Rio Pomba, Zona da Mata Mineira, Brazil, located between the coordinates of 21° 09'19.2" and 21° 09' 09.3" S and 43° 09'12.5" and 43° 08' 58.8" W, in August 2014, and then processed in the fruits and vegetables processing unit.

To evaluate the effects of different storage temperatures, the juçara fruits were selected and any green (immature) fruits or those with signs of deterioration were discarded. They were subsequently weighed, washed and maintained in containers with drinking water at room temperature for 5 minutes. After this step, the fruits were sanitized with a chlorinated solution containing 200 mg L\(^{-1}\) of active chlorine and rinsed in clean water containing 10 mg L\(^{-1}\) of active chlorine. Subsequently, the fruits were packed into dark flexible plastic packages and stored at 25 °C ± 2, 5 ± 2 °C and -18 ± 2 °C.

The experiment was divided into two stages. In the first stage, the fruits maintained at 25 °C, 5 °C and -18 °C were analyzed after 0, 7 and 14 days of storage. In the second stage, the frozen fruits were analyzed once a month for 6 months. For both stages the physical and chemical (pH, titratable acidity, soluble solids and mass loss), microbiological (thermo-tolerant coliforms, *Salmonella* sp.), Bioactive compound (anthocyanins, antioxidant activity - ABTS and phenolic compounds) and colorimetric (L, a*, b*, C* and h*) characteristics were analyzed.

The hydrogen ion potential (pH), titratable acidity (% citric acid) and soluble solids (ºBrix), were determined according to the Association of Official Agricultural Chemists - AOAC (2010), and mass loss was determined by the gravimetric method described by Pompeu et al. (2009).

The coliform counts were determined as follows: 25 g portions of the fruits were homogenized in 225 mL of 0.1% peptone water (10\(^{-1}\)) and serial dilutions prepared of up to 10\(^{-3}\) from this initial dilution. Fecal coliforms were determined using the Most Probable Number (MPN) technique (KORNACKI; JOHNSON, 2001). The presence of *Salmonella* sp. was determined according to the methodology recommended by Andrews et al. (2001), and lactose broth was used for pre-enrichment.

The total phenolic compound and anthocyanin contents and antioxidant activities were determined using fruit extracts. The extracts were prepared using 25g of juçara fruit in 100 mL of
solvent (mixture of 70% ethanol: 30% water (v/v), acidified to pH 2.0 with 5.0 mol L\(^{-1}\) HCl). The infusion was allowed to stand for 48 hours in the absence of light under refrigeration at 5 °C ± 2° C. The extract was then filtered and the ethanol evaporated off at low temperature in a rotary evaporator. The extract was stored at -18 °C in the absence of light.

For the accurate determination of the juçara phenolic compounds, the extracts were purified by solid phase extraction (SPE) using a C18 separation cartridge (Waters Sep-Pak® Vac 35cc).

The total anthocyanin content of the extracts was determined using a spectrophotometer at 535 nm, according to the methodology described by Lees & Francis (1972).

The phenolic compounds were determined using the Folin-Ciocalteau reagent method, according to the methodology described by Singleton et al. (1999). The results were expressed in mg of gallic acid equivalents (GAE) per 100 g of sample (mg GAE 100g\(^{-1}\)).

The TEAC test was carried out using the cationic radical ABTS\(^{**+}\) according to the methodology described by Re et al. (1999). The results were expressed in μM L\(^{-1}\) trolox equivalents per g of sample (TEAC).

The colorimetric evaluations were carried out with both juçara fruits and their extracts, obtained as described above. The color parameters L*, a*, b*, C* and \(\theta\)h* were determined using the Konica Minolta colorimeter (CR 10 - 2007), with the CIELAB (L*, a*, b*) and CIELCH (C*, \(\theta\)h*) color scales.

The experiments were carried out using a completely randomized design, evaluating time (0, 7 and 14 days) and storage temperature (room temperature, refrigerated and frozen) with a factorial scheme and an additional factor (freshly harvested fruit) (3 x 2 + 1) with three replications. The monthly assessment experiment of the frozen fruit during 180 days was carried out using a completely randomized design with three replications. Data on the fecal coliform counts were transformed to log\(_{10}\).

The results obtained were submitted to a variance analysis (ANOVA) and the means compared by the Scott-Knott test at 5% probability. Direct comparisons between the freshly harvested fruit and the treatments were carried out using the \(t\) test at 5% probability. The statistical software R version 3.2.1 (R CORE TEAM 2014) was used for all the analyses.

3 RESULTS AND DISCUSSION

Juçara fruits possess a high concentration of phenolic compounds and anthocyanins, resulting in a high level of antioxidant activity. The storage of Juçara fruits at ambient temperature or under refrigeration caused relevant changes in the characteristics analyzed after only 14 days of storage. However, the fruit characteristics were maintained when stored at -18 °C for 180 days.
Juçara fruits have been poorly characterized, although they are very similar to açai fruits. Fresh juçara fruits presented an acidity of 0.38 g citric acid 100 g⁻¹, pH of 5.57 and total soluble solids content of 19.13 °Brix. The low acidity makes them susceptible to contamination by spoilage microorganisms and pathogens. The total soluble solids content reported in the present work was higher than that reported by Silva et al. (2014) (11.60 °Brix), showing differences in the maturity stage and storage conditions of the fruits analyzed.

After 14 days of storage, the total soluble solids content of the fruits maintained at -18 °C was 18.03 °Brix, which was not different from that of the fresh fruits (19.13 °Brix; p>0.05). The juçara fruits showed a significant reduction in total soluble solids after 14 days of storage at room temperature and under refrigeration, representing losses of 46.31% and 31.89%, respectively. This reduction can be explained by the metabolic reactions which continued to occur in the juçara fruits stored at higher temperatures.

A significant reduction of 84.21% (0.39 to 0.06 g citric acid 100 g⁻¹; p<0.05) was found in the acidity of the fruit stored for 14 days at room temperature. Also, the pH of the fruits stored at room temperature increased from pH 5.57 to 7.59 (p<0.05) after 14 days of storage. The maintenance of fruit acidity is very important since it ensures the flavor and aroma of the product, and therefore storage at room temperature is prejudicial to the processing of the fruit. The pH values and acidity of the fruits stored under refrigeration and frozen for 14 days remained similar to those observed in the fresh fruits.

The fruits stored at room temperature showed the greatest weight loss, which can be attributed to the increase in fruit respiration, which consequently lead to an increase in consumption of the reserves. However, in low temperature environments there is a reduction in fruit metabolism, and consequently a smaller weight loss is observed. In addition, the weight loss may be caused by drying of the fruit pulp, causing a loss in yield during pulping (ROGEZ, 2000). According to Chitarra & Chitarra (2005), losses of from 3 to 6% are sufficient to reduce the quality of most fruits and vegetables. This phenomenon becomes even more significant in the case of juçara fruits, since the edible portion consists of a thin layer of epicarp and mesocarp, representing an average of only 10% of the fruit weight (PEREIRA et al., 2016; PEREIRA et al., 2017).

Due to the dark color of the juçara fruits, the colorimetric analyses of the whole fruits could not be carried out, independent of time and storage temperature. Thus, only the color results for the extracts have been presented. The fresh fruit extracts showed average values for L*, a*, b*, C* and h* of 15.24, +7.36, +1.93, 7.69 and 14.53°, respectively and they also showed high contents of anthocyanins and phenolic compounds (Table 1), indicating a relationship between these compounds and the dark colors of the extracts.
No significant changes were observed (p > 0.05) for the parameters $a^*$, $b^*$, $C^*$ and $h^*$ throughout the storage time. However, a significant difference (p<0.05) was observed between the storage temperatures for the parameters of $a^*$ and $C^*$. Fruits stored at room temperature (4.81 for $a^*$ and 4.93 for $C^*$) and under refrigeration (4.14 for $a^*$ and 4.61 for $C^*$) showed lower values for these parameters when compared to the frozen fruits (6.88 for $a^*$ and 7.21 for $C^*$). These results indicated there was a loss of red color and its intensity for fruits stored at room temperature and under refrigeration, which is possibly related to the degradation of anthocyanins. Storage at -18 °C maintained the fruit color stable throughout the 14 days.

These results demonstrated that frozen fruit storage maintained the physicochemical and colorimetric characteristics stable for a longer period of time when compared to fruits stored at room temperature and under refrigeration.

The fresh fruits showed an initial contamination with thermo-tolerant coliforms of $5.9 \times 10^2$ MPN g$^{-1}$ and the absence of *Salmonella* sp. in 25 g. This initial contamination was due to the field conditions, harvesting procedures and a climate that favors microbial growth. Similar values for initial contamination were evidenced by Rogez (2000) when analyzing açai fruit.

A significant increase in the number of thermo-tolerant coliforms was found as the storage temperature increased. A similar result was observed by Pompeu et al. (2009), when carrying out microbiological analyses in açai fruit, and Rogez (2000) found that after 48 hours of storage at 30 °C, these micro-organisms had increased by up to two logarithmic cycles.

Storage at -18 °C led to a reduction in thermo-tolerant coliforms, an observation that can be explained by the effects of low temperature on microbial cells during the freezing process. At -18 °C ice crystals were formed (SCHWARTZ et al., 2008), which would lower the water activity. Furthermore, the slow freezing process used may have caused the death of micro-organisms due to the formation of large ice crystals and consequent disruption of the cell membrane. This may have occurred since micro-organisms of the coliform group belonging to the Gram-negative group of bacteria, are sensitive to cold shock, mainly due to their saturated fatty acid content, leaving the cell membrane less fluid under refrigeration (GAO et al., 2007).

The presence of thermo-tolerant coliforms above the legal limits permitted in Brazil (BRASIL, 2001) (values of above $5.0 \times 10^2$ MPN g$^{-1}$) in the juçara fruit samples stored at room temperature for 7 and 14 days, and under refrigeration for 14 days, shows the need for immediate freezing after harvest.

The juçara fruit showed high antioxidant activity, which correlated mainly with their anthocyanin and phenolic compound contents. Average values of 454.15 μM Trolox eq g$^{-1}$ were found for the antioxidant capacities of the fresh fruits (Table 1). This value is higher than that reported
for many temperate and tropical fruits (RUFINO et al., 2010; REQUE et al., 2014), but similar antioxidant activity levels were found by Pereira et al. (2018) (487.48 μM Trolox eq g⁻¹) and Moreira et al. (2017) (370.93 μM Trolox eq g⁻¹) when analyzing juçara fruit and pulp, respectively.

Anthocyanin and phenolic compound contents of 1,261.88 mg total anthocyanin in 100 g⁻¹ and 9,903.82 mg GAE 100 g⁻¹, respectively, were found in the juçara fruits (Table 1). The values for anthocyanins were higher than those observed by Pompeu et al. (2009) in açai fruit. Similar anthocyanin levels were found by Pereira et al. (2018) (1,365.21 mg of cyanidin-3-glucoside 100 g⁻¹) and Brito et al. (2007) (1,358 mg of cyanidin-3-glucoside 100 g⁻¹) when analyzing juçara fruit and by Moreira et al. (2017) (1,203 mg total anthocyanins 100 g⁻¹) when analyzing juçara pulp. The latter authors also found similar levels of total phenolic compounds in the juçara fruit (10,237.16 mg GAE 100 g⁻¹) and juçara pulp (9,778.20 mg GAE 100 g⁻¹), respectively.

Fruits kept at room temperature and under refrigeration showed higher anthocyanin and phenolic compound losses when compared with fruits maintained at -18 °C. The reduction in bioactive compounds increased with storage time (Table 1). A loss of bioactive compounds in foods stored at room temperature and under refrigeration has already been reported. A significant loss of anthocyanins was observed by Pompeu et al. (2009) in açai fruits stored at 5 and 30 °C. The reduction in antioxidant capacity and phenolic content could be due to an increased metabolism of the fruits at higher temperatures, resulting in degradation reactions.

The decrease in phenolic compound levels reported above in the juçara fruits could be related to the enzyme activity (Table 1). Polyphenol oxidase (PPO) operates in the darkening of the product by oxidation of the phenolic compounds with the consequent formation of O-quinones, which condense and produce dark, insoluble pigments, such as melanin.

The O-quinones formed may react amongst themselves or with other compounds, including dark anthocyanins, to form dark polymers (MALACRIDA; MOTTA, 2006). Furthermore, the O-quinones formed may interact with amine and thiol groups and reduce the availability of lysine, methionine, thiamine and other essential nutrients (ARAÚJO, 2008). Thus, PPO plays a pivotal role in the degradation of anthocyanins, consequently causing a nutritional loss, and should therefore be inactivated.

Anthocyanin losses may also have occurred due to oxidation catalyzed by oxidative enzymes such as peroxidase (POD) and polyphenol oxidase (PPO), responsible for darkening of the juçara samples (POMPEU et al., 2009). Furthermore, a co-pigmentation process may have taken place due to condensation between the anthocyanins and other phenolic compounds, resulting in a reduction of these compounds with time (CASTAÑEDA-OVANDO et al., 2009).
This difference between the bioactive compound contents observed in the fruit stored at room
temperature and in those stored under refrigeration (Table 1) allows for the inference that the other
phenolic compounds, or a combination of these, were responsible for maintaining the antioxidant
capacity. A similar result was observed by Reque et al. (2014) when analyzing frozen blueberry fruit
maintained at -18 °C for 6 months. In this case, the increase in antioxidant activity was attributed to
the formation of compounds with high antioxidant activity, arising from the co-pigmentation
phenomenon.

The antioxidant activity and the anthocyanin and phenolic compound contents found in this
study for juçara fruits native to southeastern Minas Gerais, were higher than those found for juçara
fruits from other regions of Brazil (RUFINO et al., 2010; LIMA et al., 2012). This observation may
be explained due to differences in maturation stage and in the storage and processing conditions of
the fruits. Another factor which may also have interfered was the method used to extract the bioactive
compounds, as evidenced by Vieira et al. (2013).

The bioactive compounds in the juçara fruit stored at -18 °C were stable for a longer time as
compared to fruits stored at 25 °C and under refrigeration at 5 °C. Considering the results for the
physicochemical, colorimetric, microbiological and bioactive characteristics after 14 days of storage,
freezing maintains the properties of the juçara fruit for 14 days.

In order to understand the behavior of long term storage under freezing conditions, the fresh
juçara fruits were maintained at -18 °C and analyzed every 30 days for 180 days. There was no
significant difference between the values obtained for time 0 and 180 days of storage time for pH (pH
5.6 and pH 5.4), acidity (0.4 and 0.3 g citric acid 100 g⁻¹) and soluble solids (19.1 and 18.2 ºBrix)
contents (Table 2). However, a variation in pH was observed for storage times of 90 and 120 days
and for titratable acidity for a storage time of 90 days (Table 2). A reduction in the loss of weight,
from 0.9 to 0.7, was reported after 120 days of storage, the value then remaining constant up to the
end of the experiment.

Araújo et al. (2009) also found no significant variation in soluble solids when analyzing frozen
blackberry nectar, and fluctuations in acidity and pH, similar to those reported in the present study
(Table 2), were also observed by these authors. Sousa et al. (2006) analyzed fresh açai juice frozen
for 120 days and also reported an increase in acidity during the first two months followed by a
reduction in this value after three months of storage. For weight loss, they reported a reduction after
120 days, then remaining constant up to the end of the experiment. Although these reported variations
were statistically significant, the quantities involved did not affect the quality of the fruit. For the
parameters of pH and acidity, the baseline parameters were maintained throughout the 180 days of
storage.
In the first month of storage at -18 °C, the juçara fruits showed a decrease in the number of thermo-tolerant coliforms from 1.6 log to 0.3 log, then remaining constant up to the end of the storage time. There was no detectable presence of *Salmonella* sp. at zero time or throughout storage. Due to the presence of coliforms below the permitted limits in Brazil (2001) and the absence of *Salmonella* sp. in 25 g of the fruit, it can be stated that storage at -18 °C is sufficient to maintain the microbiological quality for 180 days.

The antioxidant capacity of the frozen juçara fruit increased 62.84% after 6 months (Table 2). This increase in antioxidant capacity was also observed in a study carried out by Reque et al. (2014) when analyzing blueberry fruit at -18 °C for 6 months. An increase in antioxidant capacity during storage can be explained by reactions that continue occurring after harvest and during frozen storage (KALT et al., 1999). In addition, tissue damage generated by thawing of the fruit may increase the extraction of compounds having antioxidant capacity.

The anthocyanin and phenolic compound contents were found to maintain their levels up to the end of the storage period (Table 2). These results differ from those found by Moura et al. (2020), who observed a reduction in the levels of bioactive compounds after 30 days of storage in blackberry fruits stored at -20 °C.

The loss of anthocyanins may have been significant after 120 days of storage due to variability in the sample or injury to the fruit used in that sample, which may have favored the release of oxidative enzymes, and the interaction between these factors may have led to degradation of the anthocyanins (Table 2).

There was no significant difference in the colorimetric parameters analyzed during the storage period. The average values reported for the parameters were: L*=15.48, +a*=7.65, +b*=1.88, C*=7.9 and h*=14.07. Juçara fruits can be stored under freezing conditions for 180 days with no significant change in their color.

The results obtained for the physicochemical, microbiological, colorimetric and bioactive analyses demonstrate the possibility of processing companies freezing the fruits for up to 180 days, which is important in order to overcome problems of seasonality and short production periods.

**4 CONCLUSIONS**

Juçara fruits frozen at -18 °C maintained their original physicochemical properties and reduced microbiological contamination. In addition, frozen juçara fruits showed stability of the bioactive compounds and antioxidant capacity, as well as maintaining the color parameters constant. Frozen juçara fruits can be stored for up to 6 months with no loss of their properties. Thus, frozen storage is a way to bypass the main challenges to the industrial use of juçara fruits: perishability and seasonality.
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Table 1: Antioxidant capacity, and the anthocyanin and phenolic compound contents of juçara fruits stored for fourteen days at room temperature (25 °C); under refrigeration at 5 °C; and frozen at -18 °C.

|                          | Control | Time (days) | Antioxidant capacity (μM Trolox eq g⁻¹) | Time (days) | Total anthocyanin contents (mg 100 g⁻¹) | Time (days) | Phenolic compound contents (mg GAE 100 g⁻¹) | Time (days) |
|--------------------------|---------|-------------|----------------------------------------|-------------|-----------------------------------------|-------------|---------------------------------------------|-------------|
|                          | 454.15±80.33a | 7 |                         | 14 |                                         |             |                                              |             |
| Room Temperature         | 376.75±28.07 | 370.34±8.53 | 373.54±13.82b               |             |                                         |             |                                              |             |
| Refrigerated             | 328.76±26.48 | 335.31±6.32 | 320.04±14.26b               |             |                                         |             |                                              |             |
| Frozen                   | 513.35±31.14 | 485.27±30.33 | 499.31±0.58a                |             |                                         |             |                                              |             |
| Average                  | 406.29±2.37 | 396.97±13.27 |                              |             |                                         |             |                                              |             |
|                          | 1261.88±12.56a | 7 |                         | 14 |                                         |             |                                              |             |
| Room Temperature         | 613.84±36.61* | 506.63±19.85* | 560.23±11.86b*              |             |                                         |             |                                              |             |
| Refrigerated             | 580.18±40.91* | 481.74±4.27* | 530.96±25.91b*              |             |                                         |             |                                              |             |
| Frozen                   | 1297.52±63.58 | 1178.72±44.55 | 1238.12±13.46a             |             |                                         |             |                                              |             |
| Average                  | 830.51±14.49A | 722.36±B |                              |             |                                         |             |                                              |             |
|                          | 9903.82±1562.23a | 7 |                         | 14 |                                         |             |                                              |             |
| Room Temperature         | 8330.06±328.41 | 7313.66±218.31 | 7821.86±77.86b              |             |                                         |             |                                              |             |
| Refrigerated             | 6969.40±552.62 | 7187.98±344.00 | 7078.69±147.51b             |             |                                         |             |                                              |             |
| Frozen                   | 11942.08±1609.93 | 9543.17±391.16 | 10742.62±861.80a            |             |                                         |             |                                              |             |
| Average                  | 9080.51±684.40 A | 8014.94±89.35B |                                |             |                                         |             |                                              |             |

Values expressed as the mean and standard deviation. Lowercase letters compare the lines (storage temperature) and uppercase letters the columns (storage time). Means followed by the same letter are not different at 5% probability according to the Scott-Knott test. * Indicates significant difference between the treatment and the additional factor (fresh juçara) at 5% probability according to the t test.
Table 2: Physicochemical and bioactive compounds analyses of juçara fruits stored for 180 days at -18 °C.

| Time (days) | pH     | Acidity (g citric acid 100 g⁻¹) | Soluble solids (°Brix) | Antioxidant capacity (μM Trolox eq g⁻¹) | Total anthocyanin content (mg 100 g⁻¹) | Total phenolic compound content (mg GAE 100 g⁻¹) |
|------------|--------|---------------------------------|------------------------|----------------------------------------|----------------------------------------|---------------------------------------------|
| 0          | 5.6±0.1a | 0.4±0.1b                        | 19.1±0.2                | 454.2±80.3c                            | 1,261.9±12a                            | 9,903.8±1562                                |
| 30         | 5.6±0.1a | 0.34±0.1b                       | 18.1±0.6                | 510.7±6.7c                             | 1,129.1±23a                            | 9,485.5±281                                |
| 60         | 5.4±0.1a | 0.3±0.1b                        | 17.3±1.1                | 584.3±46.1b                            | 1,174.5±118a                           | 10,261.1±885                               |
| 90         | 5.3±0.01b | 0.5±0.1ª                        | 17.9±0.9                | 569.2±11.6b                            | 1,269.1±113a                           | 10,825.2±582                               |
| 120        | 5.1±0.02b | 0.3±0.1b                        | 16.8±0.4                | 701.0±91.2a                            | 647.8±194b                             | 10,594.5±1501                              |
| 150        | 5.4±0.1a | 0.3±0.1b                        | 17.3±0.8                | 676.3±19.8a                            | 988.2±115a                             | 11,485.5±715                               |
| 180        | 5.4±0.3a | 0.3±0.1b                        | 18.2±2.2                | 739.6±62.8a                            | 1,197.9±58a                            | 11786.8±599                                |

Values expressed as the mean and standard deviation. Lowercase letters express the comparison between columns (storage time). Means followed by the same letter are not statistically different at 5% probability according to the Scott-Knott test.